Interstate Technical Group on Abandoned Underground Mines

KDOT-FHWA Mine Workshop
April 25-27, 2000
Kansas City, MO

3rd Biannual Workshop
Interstate Technical Group on Abandoned Underground Mines

The workshop was held in Kansas City, Missouri at the Airport Embassy Suites Hotel on April 25-26, 2000. The workshop was divided into three technical sessions with a half-day field trip. Technical Session I was an update from each of ten states and Barry Berkovitz with FHWA. Technical Sessions II & III were comprised of presentations ranging from mining history to state of the art practices in remediation and investigations of underground mines. A field trip was taken to the Park College Underground Mine Facility.

The Kansas Department of Transportation and FHWA sponsored the workshop.

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TECHNICAL SESSION II

Wednesday, April 26th

8:00-8:30 Mining History in Kansas, Mr. Larry Brady, Kansas Geological Survey

8:30-9:00 Grout Mixes and Their Application, Mr. Clay Rathburn, Judy Co.

9:00-9:30 Geophysical Research for Subsurface Investigations, Mr. Jeff Daniels SoftEarth Associates, Inc.

9:30-10:00 I-70 Salt Deposit Subsidence, Mr. Neil Croxton, Kansas Dept. of Trans.

10:00-10:30 **Break**

10:30-11:30 Site Investigations, Risk Assessments, and Remediation for Multi-level Canadian Mines, Mr. Pat Gallagher, CTL Engineering, Inc.

11:30-12:00 Microseismic Monitoring, Mr. Wilson Blake, Consulting Mining Engineer

12:00-1:30 **Lunch**

FIELD TRIP

1:30-4:30 Field Trip to Park City Limestone Mine.
This active limestone mine quarries rock on two different levels. The mine is below Park College. The college utilizes the mine works in various ways. Discussions on the mine and the college will be presented by Mr. Dave Holberg and Mr. Don Woodard.

TECHNICAL SESSION III

Thursday, April 27th

8:00-8:50 Imaging Old Mine Works, Mr. Joel Strid, NSA Inc.

8:50-9:10 TDR in Subsidence Work, Mr. Kevin O'Conner & Mr. Charles Dowding

9:10-9:30 Case History Using Grout Bags, Mr. Dennis Boehm, Hayward Baker Inc.

9:30-10:00 MASW To Delineate Anomalies Beneath Asphalt, Mr. Rick Miller Kansas Geological Survey

10:00-10:30 **BREAK**

10:30-12:00 ***Open Forum***

KDOT-FHWA Mine Remediation Workshop

April 25-27, 2000

WORKSHOP PROGRAM

Tuesday, April 25

12:00-1:00 Registration

TECHNICAL SESSION I

Participating State and Federal agencies are asked to give a 20 minute presentation on Mine related activities in their state.

1:00-1:10	Opening Remarks	Bob Henthorne, KDOT
1:10-1:30	FHWA, Mr. Barry Berkovitz	
1:30-1:50	Arizona	
1:50-2:10	Illinois	
2:10-2:30	Iowa	
2:30-2:50	Kansas	
2:50-3:20	**BREAK**	
3:20-3:40	Kentucky	
3:40-4:00	Maryland	
4:00-4:20	Missouri	
4:20-4:40	North Dakota	
4:40-5:00	Ohio	

Group Information

Interstate Technical Group on Abandoned Underground Mines

A group of technically oriented individuals responsible for the remediation of underground mines beneath state roadways.

Common Area of Interest

The flow of information related to abandoned underground mines beneath roadways.

Goals

1. Generate and disseminate information.
2. Obtain outside funding or cooperatively share in the costs of research or other mutually benefical efforts.

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Name Search : Click Here Go

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[Main Page]

Mining History in Kansas

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Introduction

Mining of economic rocks and minerals in Kansas has been important to the development of the state and the region. From the coal mines of eastern Kansas to the salt mines of central Kansas, the mining history of the state has been both colorful and necessary for an emerging state over the last 150 years. Production from the lead-zinc mines of the Tri-State mining district of southeastern Kansas, southwest Missouri, and northeast Oklahoma was important to the nation's war effort during the first half of this century when the region was the worlds leading zinc producer and also an important lead producer.

Consideration of the important minerals won during the mining history of the state is summarized in table 1, showing the relation of important mined products during the early part of the 1900's, in 1950, and showing the latest data about Kansas production during 1998. Production (tonnage) of coal peaked in Kansas during 1917-18, while lead-zinc production peaked in 1926. However, review of table 1 shows the sharp production increase over the century of the major industrial minerals in the state, including stone (mainly limestone), salt and gypsum. The tonnage and value of gypsum in 1998 are not shown in table 1 (due to concealment policies of the U.S. Geological Survey), but both of these figures are many times larger than gypsum production and value in 1950.

With the peak year for lead-zinc production in Kansas of 1926, the relations of the same mineral products shown in table 1 (with the exception of dimension stone) are shown in table 2. Those commodities are also compared to the total production and value for those same commodities for the United States as a whole.

Zinc and Lead Mining

The zinc-lead mines of Cherokee County (Kansas)--especially around the towns of Galena, Treece, and Baxter Springs, produced nearly 2.9 million tons of zinc and 0.7 million tons of lead from approximately 115 million tons of mined ore (table 3, from Stewart, 1986) over the life of the district. The Tri-State district (fig. 1) in all three states produced nearly 12 million tons of zinc and 2.9 million tons of lead (table 3). The earliest period of lead mining in Kansas was probably in Linn County in the 1830's, but the first commercial production of lead in the state was near Galena in 1877 (Schoewe, 1958, p. 418-421). Nearly all of the lead and zinc was won by underground mining methods; however, some strip mining of the ores was tried in the Galena area. An important summary article discussing the geology of the Tri-State district is presented by Brockie, Hare, and Dingus (1968)--geologists with Eagle-Picher Industries, the principal mining company in the Tri-State. McKnight and Fischer (1970) completed another comprehensive study of the huge Picher field--located in Oklahoma and Kansas in the western part of the Tri-State.

The Tri-State mining district was the leading zinc-mining district in the world for nearly half a century, and it was also an important producer of lead, silver, cadmium, germanium, and gallium (Hagni, 1986, p. 30). Mining of lead-zinc ended in 1970 with the closing of the Eagle-Picher Industries Swalley Mine near Baxter Springs and the closing of the Eagle-Picher central mill at Cardin, Oklahoma. Nearly all ore production of this district was from carbonate rocks of Mississippian age, with the most important production in the district coming from a zone called the "M" bed or the "Joplin member" of the "Boone formation". An informal system of zoning of the local rock units (Beds B through R) is commonly used in the Tri-State region that was developed by Fowler and Lyden (1932). This system along with local formal and informal stratigraphic units is shown in figure 2, with the important ore "beds" emphasized on the zoning system by Hagni (1986, p. 31). For formal stratigraphic unit names in the area refer to Thompson (1986), Ebanks and others (1979), and Baars and Maples (1998).

As a result of the extensive mining in the Tri-State district are many hazards that continue to exist to the present time although considerable effort was made by local, state, and federal governments to correct many of the mine hazards. McCauley and others (1983) summarized the physical hazards in the Kansas portion of the Tri-State (table 4), and also a listing of the total acres disturbed by mining in the Kansas portion of the district (table 5).

These extensive physical problems highlighted by McCauley and others (1983) were recognized as major problems to future development of the area. Efforts were made to mitigate the hazards by local citizens, the Kansas Department of Health and Environment (KDHE), the U. S. Bureau of Mines (USBM), and the U. S. Environmental Protection Agency (EPA). The efforts of the KDHE and EPA were primarily concerned with the heavy metals in the groundwater and surface waters of the area as well as the general background levels of certain portions of the mining district. The physical hazards (subsidence, open shafts, etc.) were the primary concern of the U. S. Bureau of Mines and local citizen groups. The USBM funded the hazard study in Kansas, and similar studies in Missouri by McFarland and Brown (1983), and in Oklahoma by Luza (1983). Dressel, McFarland, and Brown (1986) summarized these hazard studies for the entire mining district.

Coal Mining

Deposits of bituminous coal are widespread in the Pennsylvanian rocks of eastern Kansas, with coal production recorded from all but two counties having Pennsylvanian rocks present at or near the surface. Both deep mining and surface mining methods were used in the past to win the coal from at least 20 different coal beds. General stratigraphy of the Pennsylvanian rock units is shown in figure 3. The most important coal mining in the state was in southeast Kansas where coal beds within the Cherokee Group were extensively mined in portions of Cherokee, Crawford, and Bourbon counties. Most important of the coal beds was the Weir-Pittsburg coal, and the extensive distribution of underground mining of this coal by room-and-pillar methods is shown in figure 4. Where the Weir-Pittsburg coal was also mined by strip-mining methods total production of the Weir-Pittsburg coal represents about two-thirds of the coal mined in the state.

Another area of extensive deep mining was in Osage County where the Nodaway coal of the Wabaunsee Group was mined by both deep and surface mining methods. In this area the Bell #4 mine south of Burlingame (Osage County) was the last deep coal mine to operate in Kansas, closing in 1964. Deep coal mining at depths around 700+ feet occurred in eastern Leavenworth County where some mines extended under the Missouri River into the state of Missouri. Coal deep-mined in Leavenworth County for the deep mines was mainly from the Bevier coal of the Cherokee Group. The last deep mine operating in Leavenworth County was the Kansas State Prison Mine at Lansing that used convict labor and this mine closed in 1947. The old longwall mining system was used for the deep mining in Leavenworth and Osage counties as compared to the room-and-pillar mining system used in southeast Kansas coal mines.

Coal deposits in Kansas have been exploited for nearly 150 years with a total coal production of approximately 300 million short tons. Peak years for coal production was 1917 and 1918, with production for each year at about 7.25 million tons. The earliest coal mining in Kansas was from mines in the Leavenworth area where the coal was important for Fort Leavenworth (established in 1843), and later the coal was used and moved by large boats and barges on the Missouri River. Mining of coal in the Osage County area was important for early railroads, and the coal mines influenced the location of the rail lines to the southwest.

In the late 1800's the coal mines in southeast Kansas became the important coal-producing region of the state due to the abundance of coal and the thickness and quality of the coal. This area dominated coal production until the mid 1970's when the Pittsburg & Midway Coal Mining Company Mine #19 shut down in Cherokee County, and P&M started full production at their Midway Mine in Linn County, Kansas, and Bates County, Missouri, mining the Mulberry coal (Marmaton Group). From that time to the present, Linn County periodically became the dominant county over Crawford County although the P&M Midway Mine closed in 1990.

For the last three and one-half years (1997-2000), Linn County coal production was the largest of any county in the state, and in 1999 and 2000 the only commercial coal production was from Linn County (414 thousand tons in 1999). General distribution of coals having the potential for surface mining in eastern Kansas (Pennsylvanian age) is shown in figure 5. In north central Kansas there are areas of thin lenticular lignite deposits from which a total production of about 300,000 tons was mined from more then 150 small mines (Schoewe, 1958, p. 378-79). These lignite deposits were present in the upper part of the Dakota Formation (Lower Cretaceous age).

Industrial Minerals

The principal industrial minerals of Kansas emphasized in this study are those minerals and rocks that were mined wholly or in part by underground methods. These "minerals" include salt, gypsum, and stone (especially limestone) for crushed stone and building or dimension stone. Included in industrial minerals mined in Kansas entirely by surface methods are the sand and gravel deposits, volcanic ash, clay and shale for ceramic products, and diatomaceous marl. These industrial minerals will not be discussed in this paper, but their general distribution is shown in figures 6 and 7. Large volumes of sand and gravel are extracted from the floodplains, channels, and terraces of Kansas rivers, and from the large deposits of Tertiary sand and gravel of the high plains in the western part of Kansas. Although used primarily for road and construction purposes, some quality sand is used as industrial sand for fiberglass manufacturing and for sand blasting applications. Grisafe (2000) compiled a listing of nearly 6,300 locations of abandoned industrial mineral pits, quarries, and mine locations in Kansas. In addition, a second compilation (Grisafe and Baker, 1999) lists a total of 879 active industrial mineral pits, quarries, and mine locations (active during 1998) in the state. The general distribution of industrial minerals in Kansas is shown in figures 6 and 7.

<u>Salt</u>—Extensive deposits of salt are present in the central part of the state that have been exploited for economic purposes by underground mining methods and solution mining efforts. Rock salt was first discovered in Kansas in 1887 while individuals were exploring for oil and gas (Schoewe, 1958, p. 437). The important commercial salt bed in the state is the Hutchinson Salt Member of the Wellington Formation (Lower Permian). Distribution and general thickness of the Hutchinson salt is shown in figure 8. Three mining companies are presently mining the salt by underground mining methods including the Hutchinson Salt Company (Reno County), Lyons Salt Company (Rice County), and the Independent Salt Company (Ellsworth County). Depths of mining range from 645 feet with the Hutchinson Salt Company to 1045 feet with the Lyons Salt Company. At least five additional deep mines have operated in Kansas that are no longer mining salt. Among these five mines, two operated in Rice County, two in Ellsworth County, and one in Kingman County. Besides the companies with operating shaft mines, three salt companies presently have solution mine fields—three fields in Reno County and one in Rice County. A fourth company solution mines salt in Sedgwick County for chlorine chemical manufacturing.

In addition to the Hutchinson salt, there are extensive salt deposits within the Nippewalla Group (Holdoway, 1978) that are not commercially developed. These deposits are stratigraphically higher--but still within Lower Permian rocks, with the salt beds generally west of the Hutchinson salt beds.

Extensive discussion of the Kansas salt deposits and salt mining methods are available in reports by Taft (1946), and Walters (1978). In the Walters report, emphasis is placed on land subsidence due to salt dissolution by improperly designed brine fields, and improperly plugged oil wells that penetrated the thick salt beds. Watney (1980) determined detailed distribution of the Hutchinson salt in Kansas.

<u>Gypsum</u>—Deposits of gypsum are present in several geologic units within Lower Permian rocks of central Kansas. General distribution of the gypsum deposits is shown in fig. 6. Two gypsum mines still operate in the state, and based on the report of Kulstad and others (1956) there were at least 19 mines in ten counties in the state. In Marshall County in the northern part of the state, the Georgia Pacific Gypsum Corporation mines gypsum from shallow depths using underground methods. The gypsum is mined from gypsum beds that are about eight to nine feet thick in the Easly Creek Shale Formation in the upper part of the Council Grove Group. In the south-central part of Kansas, the National Gypsum Company mines the Medicine Lodge Gypsum Member of the Blaine Formation in the upper part of the Nippewalla Group. National Gypsum now mines gypsum primarily by surface mining methods in northwest Barber County; however, they also

have a shallow underground mine where they obtain their purest gypsum for high quality plaster. Maximum thickness of the gypsum bed in the area of the mine is about 30 feet.

Most of the gypsum mined by the two active companies is calcined for use in wallboard or plaster. The company plants where the gypsum is processed is located near the mine (Georgia-Pacific) or shipped about 20 miles to the plant (National). Raw gypsum is also used in manufacture of portland cement, and as a soil additive for agriculture purposes.

Stone—Throughout the eastern third of Kansas, stone is quarried and crushed for use in cement manufacture, concrete aggregate, agriculture lime, and as road metal. Limestone from Pennsylvanian, Permian, and Cretaceous rocks is commonly used for crushed stone in the state. Sandstone from some Pennsylvanian rocks is used in cement manufacture, and calcite-cemented sandstone in Lincoln County (limited areas of Dakota Formation sandstones within Lower Cretaceous rocks) is extensively used where high quality aggregates are needed in the western part of the state. A general distribution of the stone quarries and mines in Kansas are shown in fig. 7.

Underground limestone mining operations have been important for years in the Kansas City area, and in the Bonner Springs (underground operations recently closed) and Atchison areas. Currently two underground limestone mines are operating in the Kansas City (Kansas) area, including one mine in Johnson County (mining the Argentine limestone Member of the Wyandotte Limestone) and one mine in Wyandotte County (mining the Bethany Falls Limestone Member of the Swope Limestone). In Atchison County there are three limestone mines, each mining the Plattsmouth Limestone Member of the Oread Limestone.

Limestone for building stone has been extensively quarried in Kansas. At the present time most of the building stone is quarried from Lower Permian limestone units. Important limestones used in recent years by producers (Grisafe, 1976) include certain ledges in the Fort Riley Limestone Member of the Barnston Limestone (with trade names of "Silverdale" and "Junction City", dependent on the location mined), the Cottonwood Limestone Member of the Beattie Limestone, and the Funston Limestone Formation ("Onaga"). Other Permian limestone units quarried include the Five Point Limestone ("Chestnut Shell") where it is developed as a local coquina in Pottawatomie County, that is a member of the Janesville Shale, the Neva Limestone member of the Granola Limestone, and the Cresswell Limestone Member of the Winfield Limestone.

Important in the western part of the state for building stone are the thick Fort Hays Limestone Member of the Niobrara Chalk, and the Fencepost limestone bed of the Greenhorn Limestone. These units are present in Upper Cretaceous rocks and located in west central Kansas. Another Cretaceous unit that has been used for building stone is the Dakota Formation in areas where well-cemented sandstone beds exist (Risser, 1960).

Within the Pennsylvanian rocks of Kansas, various limestone units were used for local building stone. Limestone units described by Risser (1960) as having more extensive use are the Kereford Limestone and Toronto Limestone members of the Oread Limestone, and the Westerville Limestone Member of the Cherryville Shale. In Bourbon County, the Bandera

Quarry Sandstone Member of the Bandera Shale was extensively quarried and had widespread use in the region. A good summary of the Kansas building stones--their quarrying, processing, and use is summarized in Schoewe (1958, p. 443-457), Risser (1960) and Grisafe (1976).

Summary

1. Mining in Kansas is now mainly involved with the extraction of industrial minerals. Mine production and value of industrial minerals has continuously increased over the last century as a result mainly of the growing population of the state. In contrast, the zinc-lead industry developed around the large Tri-State mining district no longer produces these metals in Kansas or in the Missouri and Oklahoma portions of the district. Production of coal was also very important in the first half of the 20th century, but coal production has been reduced to the small amount of about 400 thousand tons/year (1999) from a peak yearly production of 7.25 million tons in 1917 and 1918.

2. Zinc and lead mining in the Tri-State district closed in 1970 after production of nearly 12 million tons of zinc and 2.9 million tons of lead. Kansas contributed about 25 percent of that metal amount for the district—a district that lead the world in zinc production for nearly 50 years. As the result of this extensive mining of metals, there are a number of hazards that develop over time such as mine collapses, and open shafts. McCauley and others (1983) recognized a total of 910 hazards for the Kansas portion of the Tri-State district. Work by a number of government agencies, and local citizen groups has helped mitigate a number of these hazards since the time of the McCauley study.

3. Coal mining existed in most counties in the eastern part of Kansas, but the most important area mined for coal was in southeast Kansas—primarily in Crawford and Cherokee counties. Coal was won in that area by extensive underground mining of the Wier-Pittsburg coal. Surface mining of the Weir-Pittsburg coal and other coals of the Cherokee group were also very important in those counties and in Bourbon County. For the past 25 years Linn County has periodically become the important coal-producing county in the state, and it is now (2000) the only Kansas county with producing coal mines..

4. Extensive deposits of Hutchinson salt exist in the central part of the state with a salt thickness up to 400 feet. Those salt deposits have been mined since the 1870's. At the present time there are three shaft mines, and five solution mine fields, that are mining this commodity for use in Kansas and the region.

5. Stone production in the state is another very important commodity for our developing economy. Limestone is widely distributed in eastern Kansas and in portions of north central Kansas. The limestone is used as concrete aggregate, road metal, agricultural lime, building stone, and in the manufacturing of cement. Sandstone is produced in limited areas of the state and it is also used for most of the same uses of limestone, except for agriculture lime, and a more restricted use in cement production. Six underground mines exist in northeastern Kansas that produce crushed limestone for the local building and road construction industries.

6. Deposits of gypsum exist in a general north-south direction across central Kansas. These gypsum deposits have been actively worked by both underground and surface mining methods. Two gypsum mines now operate in Kansas, one in the northern part of the state and the other in the southern part. The most important use of the gypsum is for manufacture of wallboard and plasters. Other uses include its use as an agriculture soil additive, and in the manufacture of cement.

7. Zinc, lead, coal, salt, gypsum, and stone have all been won entirely or in part by underground mining methods in Kansas. Results of those efforts have been important to the economy of the state. However, the space left after mining and the weakening of the overlying rocks with time present potential hazards. These problems must be recognized by geologists and engineers now and in the future as they cope with subsidence, collapse, and weakening rock when roads, buildings, and other structures are constructed over those problem areas. This report provides those geologists and engineers with some general idea of the distribution and amount of mining that was conducted in Kansas. Many key references have been provided to permit further investigations of the mineral resources, or potential problems associated with the winning of those mineral resources.

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TABLE 1. Kansas mining production and values for selected commodities — 1914, 1950, 1998.

Commodity#	1914*		1950**		1998p***	
	1000 st.	$ million	1000 st.	$ million	1000 st.	$ million
Zinc (metal)	10.6	1.08	27.2	7.72	--	--
Lead (metal)	1.40	0.11	9.49	2.56	--	--
Coal	6,860	11.2	2,030	7.96	345(a)	7.76(b)
Stone (crushed)	884	0.60	7,590	8.23	24,900	102
Stone (dimension)	--	--	44.2	0.69	24.3	1.55
Salt	416	0.92	846	5.91	3,560	121
Gypsum	111	0.31	333	0.76	(c)	(c)

\# Other mined commodities not included in this summary are sand and gravel, volcanic ash, and clay and shales

* U.S. Geological Survey (1916a,b) Mineral Resources of US - 1914
** U.S. Bureau of Mines (1953) Minerals Yearbook - 1950
*** Tanner and Grisafe (1999), USGS Mineral Industry Surveys - Kansas 1998 est. (1999)

(a) Kansas Department Health and Environment -- Surface Mining Section information
(b) Estimate
(c) Data not released

TABLE 2. Kansas and U.S. mining production and value for selected commodities — 1926.

	KANSAS*		US*	
	1000 st.	$ million	1000 st.	$ million
Zinc	126	18.9	612	91.8
Lead	28.5	4.55	681	109
Coal	4,010	12.5	601,000	1,660
Stone (crushed)	851	1.06	124,000	188
Salt	730	2.74	7,371	25.1
Gypsum	195	1.22	5,640	46.7

*U.S. Bureau of Mines (1929a,b), Mineral Resources of the U.S. — 1926.

TABLE 3. Mine production by states of the Tri-State Mining District.

State	Operating Period	Est. Tons Mined (st)*	Recoverable Metal (st) Lead	Recoverable Metal (st) Zinc
Missouri	1850-1957	196,000,000	885,390	3,618,930
Kansas	1876-1970	115,000,000	691,338	2,900,000
Oklahoma	1891-1970	187,000,000	1,306,679	5,219,998
Totals (Metal)		498,000,000	2,883,407	11,738,928
Average Grade (% Metal)			0.579	2.357

(*) Figures rounded to nearest one million tons, and consist of estimated tonnages for 1850-1906 and 1946-1970 periods.

Modified from Stewart (1986, p. 22)

TABLE 4. Summary of hazards in Kansas portion of the Tri-State Mining District.

Mining Area	Adits	Open Pits	Surface Collapses	Uncollapsed Open Shafts	Collapsed Open Shafts	Total Hazard Shafts	Total Hazards	Total Shafts
Waco	0	0	24	3	10	13	37	42
Lawton	0	0	9	0	5	5	14	33
Badger-Peacock	0	1	7	5	20	25	33	141
Crestline	0	0	5	0	15	15	20	23
Treece	0	0	17	18	62	80	97	189
Baxter Springs	0	0	36	11	63	74	110	151
Galena	6	7	209	11	366	377	599	2966
Totals	6	8	307	48	541	589	910	3545

Modified from McCauley and others (1983, p. 34)

TABLE 5. Mining affected areas in the Kansas Tri-State Mining District.

Mining Area	Approximate area covered by mine and mill waste (Acres)	Approximate area of known underground mining (Acres)
Waco	(150)	(85)
Lawton	(19)	(11)
Badger-Peacock	(27)	(41)
Crestline	(45)	(34)
Treece	(747)	(1273)
Baxter Springs	(449)	(530)
Galena	(891)	(246)
Totals	(2328)	(2220)

Modified from McCauley and others (1983, p. 34)

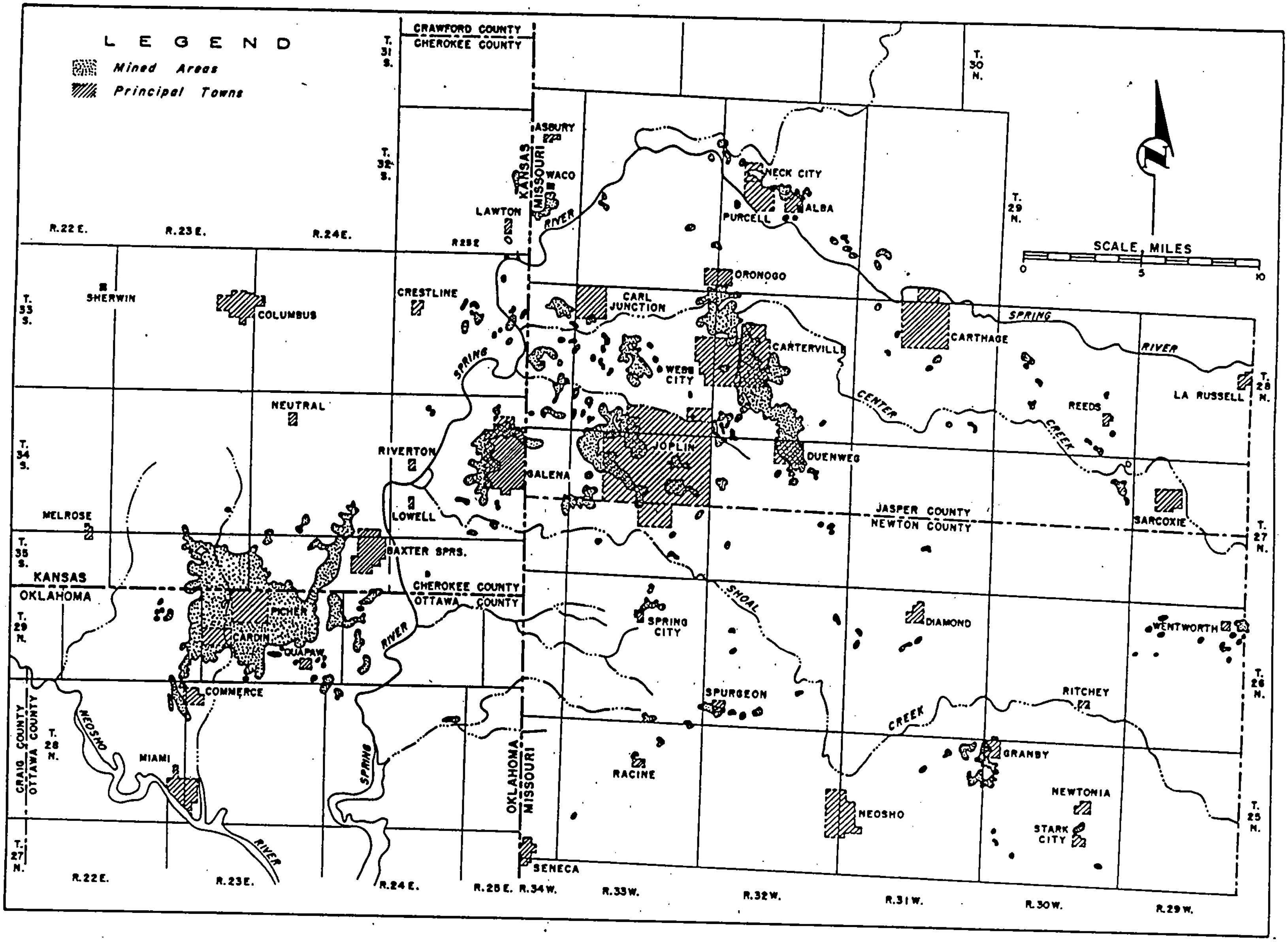

FIGURE 1. Principal portion of the Tri-State mining district, showing general mined areas. Modified from Brichta (1960, p. 5).

System	Series	Fm./Mbr.		Bed	Thickness (m.)	Lithology	Importance as an Ore Horizon
Pennsylvanian	Desmoinesian Morrowan & Atokan	Several Fms. & Mbrs.			0-90	Dark sh. & ss.	Minor importance
Mississippian	Chesterian	Several Fms. & Mbrs.			0-30	Ls. cong., sh. & ss.	Minor importance
Mississippian	Meramecian	Quapaw Ls. Fm.			0-9	Ls.	Unimportant
Mississippian	Meramecian	Boone Formation	Moccasin Bend Mbr.	B	0-6	Ls.	Minor
				C	0-10	Ls. & chert nod.	Minor importance
				D	5.5-7	"Cotton rock" & chert	Unimportant
				E	1.5-2.5	Ls. and chert nod.	Important
				F	3.5-4.5	"Cotton rock" & chert	Unimportant
				G H	9-12	Thin bedded chert & ls.	Important
			Baxter Springs Mbr.	J	0-12	Glauconitic, shaly ls. & chert	Minor importance
				K	0-12	Ls. & chert nod.	Very important
				L	0-11	Chert	Unimportant
			Short Creek Oolite Mbr.		0-3	Oolitic ls.	Unimportant
	Osagean		Joplin Mbr.	M	0-21	Ls. & chert nod.	Most important
			Grand Falls Chert Mbr.	N	6-9	Chert	Unimportant
				O	2.5-3	Thin bedded chert & ls.	Important
				P	0-3	Chert	Unimportant
				Q	0-3	Thin bedded chert & ls.	Unimportant
			Reed Spring Mbr.	R	15-30	Ls. & dark chert nod.	Important
			St. Joe Ls. Mbr		4.5-20	Ls. & chert nod.	Unimportant
	Kinderhookian		Northview Fm.		1.5-3	Sh.	Unimportant
			Compton Fm.		1.5-3	Ls.	Unimportant

FIGURE 2. General stratigraphic column for Mississippian rocks in the Tri-State mining district showing various "beds". Modified from Hagni (1986, p. 31).

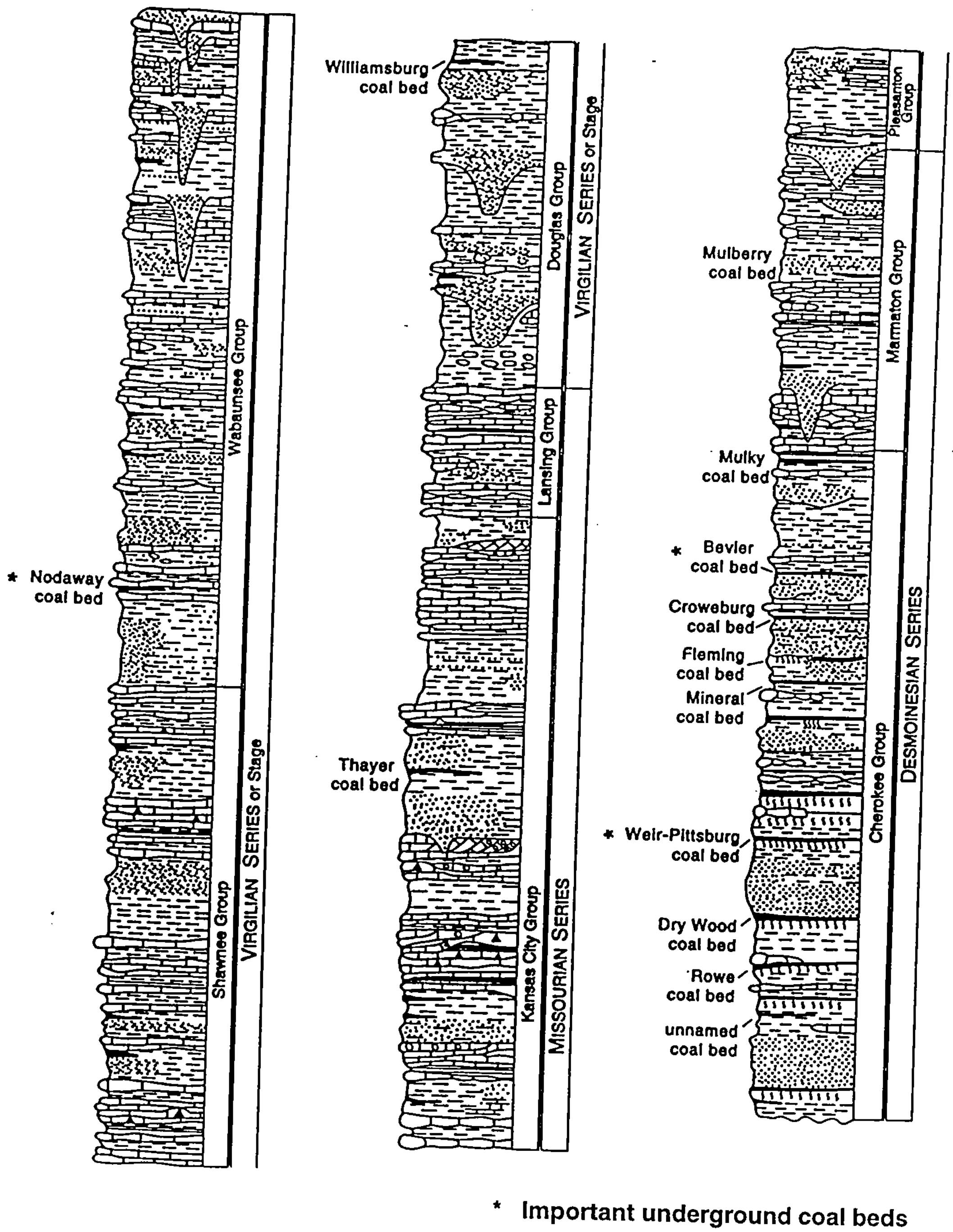

FIGURE 3. General Pennsylvanian stratigraphic column in Kansas showing coal beds that were extensively mined by underground mining in the state.

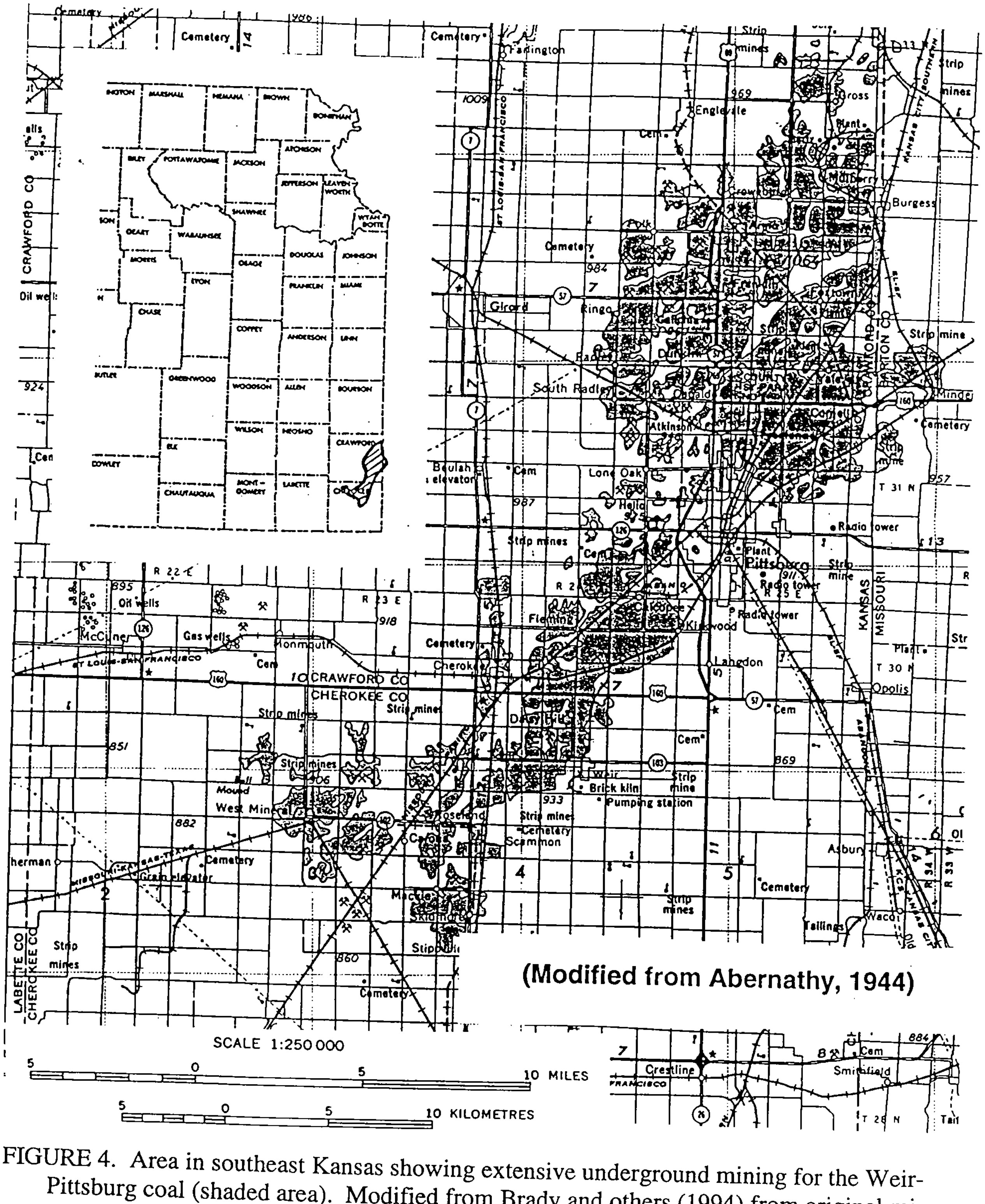

FIGURE 4. Area in southeast Kansas showing extensive underground mining for the Weir-Pittsburg coal (shaded area). Modified from Brady and others (1994) from original mine distribution by Abernathy (1944).

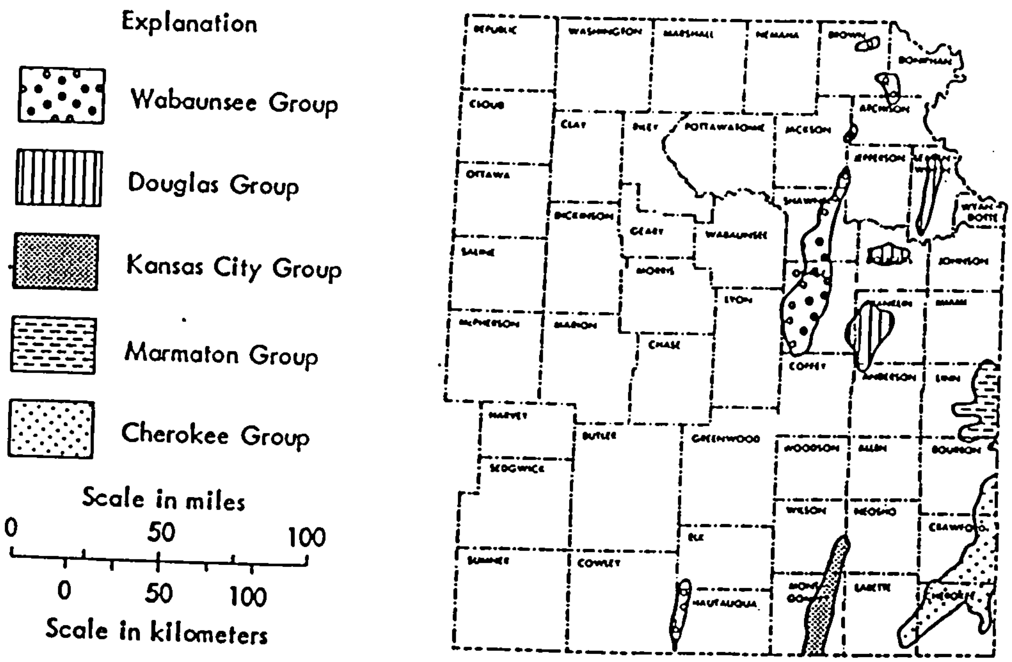

FIGURE 5. General distribution of strippable coals by geologic group in eastern Kansas. From Brady and others (1976, p. 18).

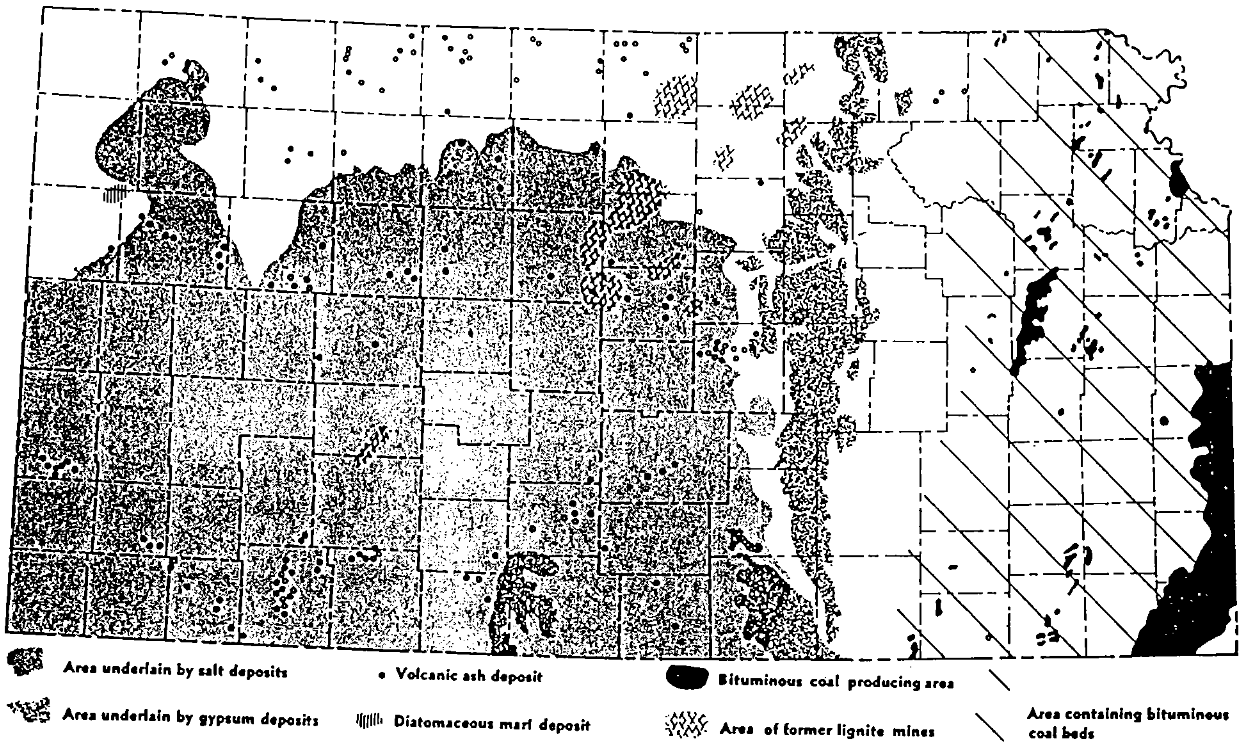

FIGURE 6. General distribution in Kansas of coal, lignite, salt, gypsum, volcanic ash, and diatomaceous marl. Modified from Hambleton and others (1961, p. 12).

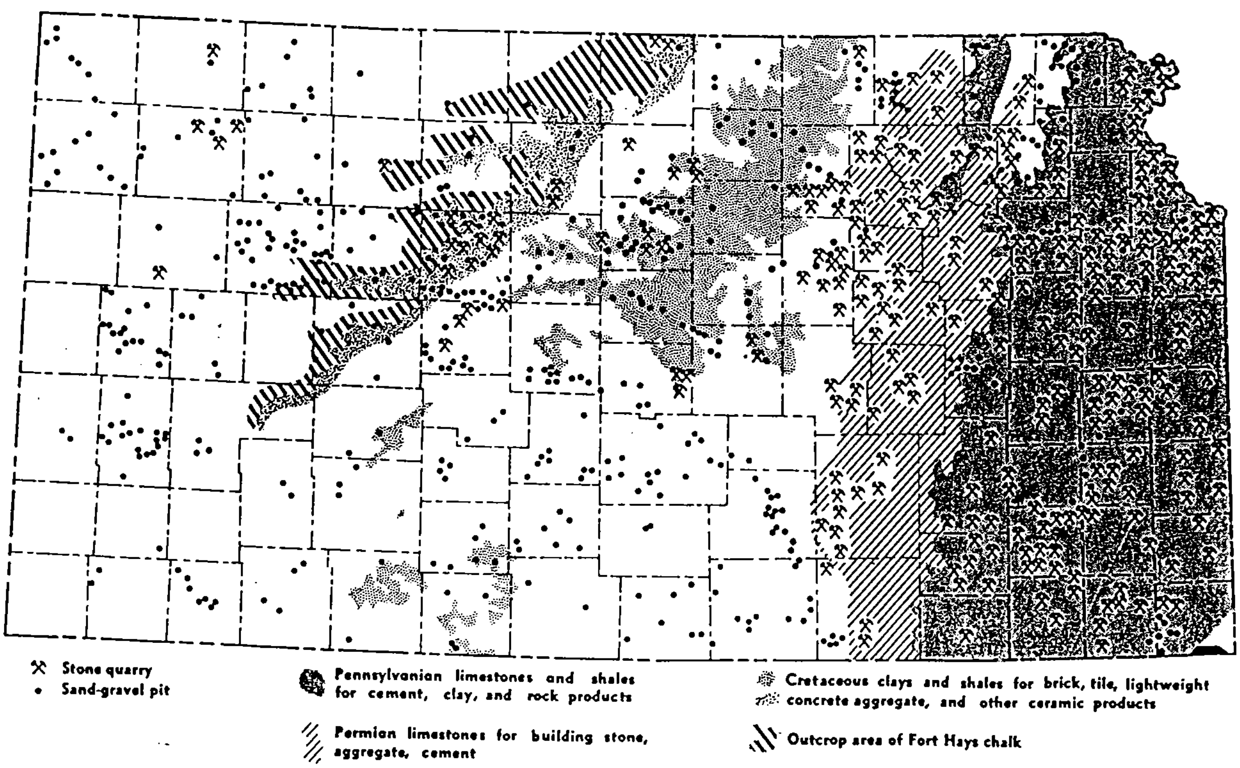

FIGURE 7. General distribution in Kansas of stone quarries and mines and sand-gravel pits. Modified from Hambleton and others (1961, p. 12).

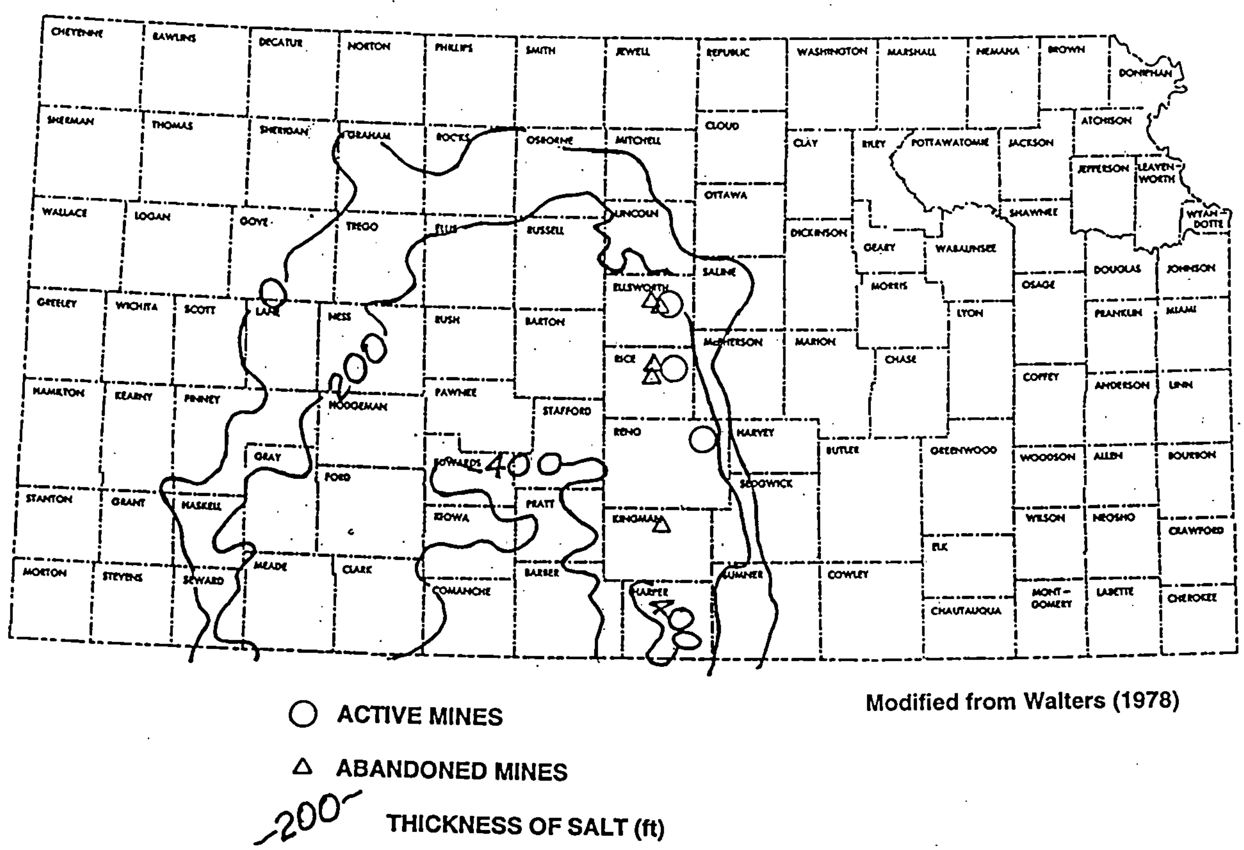

FIGURE 8. General distribution and thickness of the Hutchison salt in central Kansas, and location of shaft mines that mine the salt. Modified from Walters (1978, p. 3).

Subsidence on I-70 in Russell County, Kansas Related to Salt Dissolution—A Short History[1]

Presented by
Neil M. Croxton[2]

Abstract

A short section of Interstate 70 in Russell County, Kansas crosses two active sinkholes. These sinkholes have slowly and steadily pulled down the driving lanes since construction of the highway in the mid-1960's. They are the result of dissolution of a thick salt bed over 1300 feet below the surface. Oil drilling activity has allowed fresh water to pass through the salt, dissolving a considerable volume of it and causing the overlying strata to sink. The two areas of interstate have been regraded at significant cost, and efforts were made in 1986 to stop the subsidence at one of the sinkholes, but the lanes continue to drop. Eventually, a nearby bridge will have to be replaced because of the subsidence. The Russell County sinkholes continue to be costly objects of attention to engineers and geologists at the Kansas Department of Transportation.

Discovery of the Crawford Sink

All highway construction in Kansas first has a geology survey. When geology crews began their preliminary studies for this section of I-70 in the early 1960's, there was a large pond along the right-of-way six miles west of Russell. They noticed that the pond appeared rather deep, and although it was situated in a streambed, apparently had no dam. Asking around among local residents, Highway Commission geologists were told that the pond had always been there. An 83-year-old woman who had lived in the area all of her life reported that there had been a pond in that location ever since she could remember. So little additional thought was given to the mysterious origin of the pond. During construction, it was filled in and the highway was built, along with a nearby bridge to carry county traffic over the interstate. Final grading for the new lanes was finished in the spring of 1966.

But something was wrong. Just east of the new bridge, exactly where the pond had been, the subgrade kept dropping. Since it was a stream crossing and a fill section, Highway Commission officials at first just assumed that the fill dirt was settling. But it wasn't just the lanes that were sinking. A few quick level runs confirmed the worst—the new interstate, the pride of Western Kansas, had been built right over a sinkhole.

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[1] Presented at the KDOT 2000 Abandoned Underground Mine Workshop in Kansas City, Missouri, April 25-27, 2000.

[2] Neil M. Croxton is the KDOT Regional Geologist for the northwest portion of the state, including the subject area.

The summer of 1966 was a busy one for our geology crews. While I-70's lanes were being paved on either side, geologists and their technicians scrambled to find out what was causing the sinking. Someone thought to check air photos of the region that were taken in the 1950's. There was no pond. The locals had been wrong—the deep pond with no dam was a relatively new feature. And the State Highway Commission of Kansas had a big problem.

Cause of the Subsidence

I-70 in this area is aligned through the heart of the Gorham Oil Field. It is a very densely-drilled portion of the state, and although sinkholes hadn't caused much trouble at the time, geologists quickly suspected that the subsidence was caused by improper plugging of abandoned wells. Research into oilfield geology and deep groundwater movement led the Highway Commission to the cause—dissolution of the Hutchinson Salt Member.

This salt bed is Permian in age, a member of the Wellington Formation. In western Russell County, the Hutchinson Salt is 270 feet thick and its top is 1300 feet below the surface. Above the salt are three sandstone units—the Dakota Formation, the Cheyenne Sandstone Formation, and the Cedar Hills Sandstone Formation. All three have considerable flows of fresh or brackish water.

Oil wells in the Gorham field were drilled through the salt to a structural high in the Lansing-Kansas City Group and the Arbuckle Group. Hundreds of wells were drilled here beginning in the 1920's; many have since been abandoned. If an abandoned well is not plugged correctly, the fresh water flowing through the overlying sandstones pours down the borehole to replace water taken out of oil-producing layers by nearby active wells. On the way down, the fresh water washes across the salt face, dissolving it. The cavity in the salt grows, and eventually overlying beds sag downward until the depression shows up on the surface.

The sinkhole east of the bridge was named the Crawford Sink, after the Crawford oil lease. There are two wells 50 feet apart at the center of the sink. They are the Crawford 12 and Crawford 16. Both were drilled in 1937 and abandoned in the early 1940's.

Investigation of the Sinkholes

Geologists with the State Highway Commission of Kansas realized that the highway was probably safe as long as the sinking continued. But I-70 was too important a project to take chances with, so during that summer of 1966, before the highway opened, a test hole was drilled. Geology crews drilled a core hole down 240 feet in the Crawford Sink. (This remains the deepest hole ever drilled by our crews). They found only solid bedrock the entire way. The geologist who logged the hole called them, "as perfect cores as you could ever find in that section". They also drilled and dug down to the Fencepost Limestone Member , which is close to the surface here. A structural contour map was drawn that showed the bowl-shaped drop in strata. Officials were reasonably sure that there was not a void under the highway which could suddenly collapse.

About that time, still before the highway was open, construction crews had more bad news: another section of road wasn't holding its profile. This area was a half-mile west of the Crawford Sink. The oil well responsible was the Witt A#1, just south of the right-of-way. This well was drilled in 1937 and plugged in 1957.

Highway Commission engineers and geologists got together late that summer to decide how to proceed. There was serious talk of rerouting the highway around the sinkholes, despite the enormous cost and delays. But the Gorham Oil Field stretches several miles to the north and south. Geologists told officials that there was no way to guarantee that a new alignment wouldn't just put I-70 over other sinkholes. Since there apparently wasn't any danger to the public, the lanes in the subsidence area were paved that fall. Interstate 70 between Russell and Hays opened on schedule on November 16, 1966.

The next summer, the Highway Commission contracted with a drilling company to drill a deep exploratory well at the Crawford site. A crew with Rosencrantz-Bemis Drilling, of Great Bend, Kansas, drilled to 100 feet below the base of the Hutchinson Salt Member, a total of 1670 feet deep. Circulation was lost at 250 feet and never regained, which was attributed to washing of loose material at and below the Dakota Formation. Analysis of a radioactive gamma-ray neutron log indicated that the salt itself was washed along its entire thickness, and had been replaced by material from above. An anhydrite marker bed 350 feet above the salt had, at that time, already dropped 36 feet. Most importantly, however, was that very few voids were found, and none of these were large or near the surface. Officials told the public that the highway was safe, and that the sinkholes would cause only minor damage to the highway.

The 1970's

Nothing was done for a few years. The sinkholes continued to get deeper and broader, and the pond at the Crawford site reformed. The Witt Sink, which formed near the top of a ridge, created a noticeable depression. By 1971, the lanes had dropped so much that they had to be regraded. During the summer of that year, both areas were brought up 5 feet and repaved at the cost of 220,000 dollars. Elevations of the lanes and the bridge were taken every 6 months, making it the most surveyed section of road in the state. The highway continued to drop at almost 6 inches per year. Public relations in the area began to sour when local newspapers figured out that the subsidence showed no sign of stopping. Still, there was no danger, and so people gradually got used to sinkholes under I-70. It became old news.

Overnight on May 1 or 2, 1978, however, a huge sinkhole suddenly opened up in a field 20 miles northwest of the I-70 sinks. This hole, in northeast Ellis County, was also centered on an old well. In a few days, the hole was 75 feet across and 100 feet deep. The press coverage of the nearby sudden collapse forced the Highway Department, now KDOT, into action once again.

Our geologists were still reasonably sure that the gradual subsidence of the highway was a good indication that nothing catastrophic was going to happen to I-70. But, primarily in response to public pressure, new studies of the problem were ordered late that year. The Kansas Department of Health and Environment (KDHE) and the Kansas Geological Survey (KGS) helped this time. Not enough money was available to do any deep drilling, but the KGS ran seismic surveys along both the I-70 sinkholes and near the Ellis County collapse. Again, no near-surface voids were found beneath I-70, and few deep voids. No satisfactory conclusions were ever drawn, however, as to why the Ellis County sinkhole behaved differently from the I-70 sinks.

In addition, the KDHE took infrared air photos of the Gorham Oil Field to try to identify new sinkholes that might be developing. The idea was that shallow surface depressions would hold water after rainfall, and therefore have lusher vegetation. Regular air photos were taken early in the morning and late in the afternoon, to try to find new sinks highlighted by shadows cast by the low-angle sunlight. Neither of these endeavors yielded much useful information. The *Hays Daily News* took credit for instigating the investigations; the uproar finally died down.

Attempt to Stop Subsidence at the Witt Sinkhole

By August of 1984, the lanes at the Witt sink were back down 8 feet. It was starting to cause sight distance problems—engineers were afraid that a stalled car at the bottom of the depression would be rear-ended. So the Witt was again regraded and repaved at a cost of nearly 500,000 dollars.

KDOT engineers in that district were beginning to get more and more concerned. There didn't seem to be any end to the subsidence, and public relations in the Hays-Russell area were a serious problem. In January, 1986, the state again contracted with a drilling company. The goal this time was to stop subsidence at the Witt sinkhole.

A hole was drilled 4 feet west of the old Witt A#1 well. Drillers attempted to shut off the flow of water across the salt by cementing shut the hole below the salt. Over 30 cubic yards of cement were pumped down the new hole, until pressure built up. Satisfied that the breach below the salt had been sealed, officials resumed their frequent surveys of the lanes. And in fact, it worked—for a while. For 6 months, the lanes didn't move. But somehow, water got around the plug and the highway quickly resumed its subsidence of 5 to 6 inches a year.

In 1988, more cement was pumped down both holes at the Witt sink. This cement was saturated with salt in the hopes that it would bond to the salt face itself. After "lubricating" the hole and cavity with 200 sacks of bentonite, drillers pumped almost 100 cubic yards of the salt-rich cement down the holes. Eventually, pressure built up to 300 psi in both wells at the same time. The voids in the immediate vicinity of the of the boreholes were filled, and KDOT geologists were again cautiously optimistic. Again, their optimism was short-lived, because water soon ate another hole in the salt and the subsidence continued.

Nothing has been done at the sinkholes since this attempt to stop movement at the Witt sink. A drilling program of several holes in a circular pattern around each original well hole would probably give the best chance of stopping the subsidence. No one can guess the quantities of cement or other fill material that would be required to fill the voids at depth. Of course, the cost of such an undertaking is a concern, especially since there is no guarantee that it would succeed.

The Bridge

The highway in the vicinity of the Witt sink can be regraded as many times as necessary. The Crawford sink is a different matter. It can't be regraded any more because of clearance requirements under the nearby bridge; the bridge is sinking, too. One end has dropped over 6 feet since it was built in 1965. At the south abutment, the east curb is now 2 feet higher than the west curb. Strangely, about the only indication that the bridge is under any stress at all is narrow cracks in the curbs just over the piers. Otherwise, the structure looks like any other 35-year-old bridge in Kansas. Our bridge engineer says it could last another 25 years.

The Future of the Russell County Sinks

Something will eventually have to be done at the Crawford sink. Either it will finally subside enough to become a sight distance problem, or water will begin to cover the roadway during storms. Since the only thing preventing us from regrading the Crawford area is the presence of the bridge, the logical step is to relocate the county road and build a new bridge at another location. Then the subsidence at the Crawford area, like at the Witt, could simply be countered by adding fill to the roadbed every so often. We recently discussed with Russell County the possibility of moving the bridge a quarter-mile west, to the area between the two sinkholes.

Meanwhile, traffic continues to go over the sinks at a count of over 11,000 vehicles a day. The Witt sink continues to drop at 5 inches a year; the Crawford is subsiding at about 4 inches a year. They will keep sinking until the Gorham Oil Field is finally abandoned and water is no longer drawn out of the strata below the salt.

Summary

Improper plugging of abandoned oil wells in Russell County led to the development of two large salt-related sinkholes beneath Interstate 70. The Kansas Department of Transportation has struggled with costly, embarrassing repairs and a failed attempt at remediation during the 35-year history of the highway. Despite knowing in detail the cause of the subsidence, an economical solution has eluded us. At present, KDOT plans to simply regrade the lanes for as long as possible. The sinkholes will continue to consume our time and resources well into the 21st century.

Acknowledgments

Most of the information presented in this paper was taken from records and reports on file at the KDOT Geology Section in Topeka, Kansas. In addition, the author would like to acknowledge valuable information gained from interviews with the following individuals, all of whom work or have worked for the KDOT: Mr. Wally Taylor, Regional Geologist, northwest region (retired); Mr. Larry Rockers, Chief Geologist (retired); Mr. Ron Sherard, Area Engineer at Hays; Mr. Lynn Washburn, Bridge Evaluation Engineer; and Mr. Wes Moore, District Maintenance Engineer at Norton. Recognition is also given to the Photo Section in Topeka for their assistance in preparing the slides for the presentation.

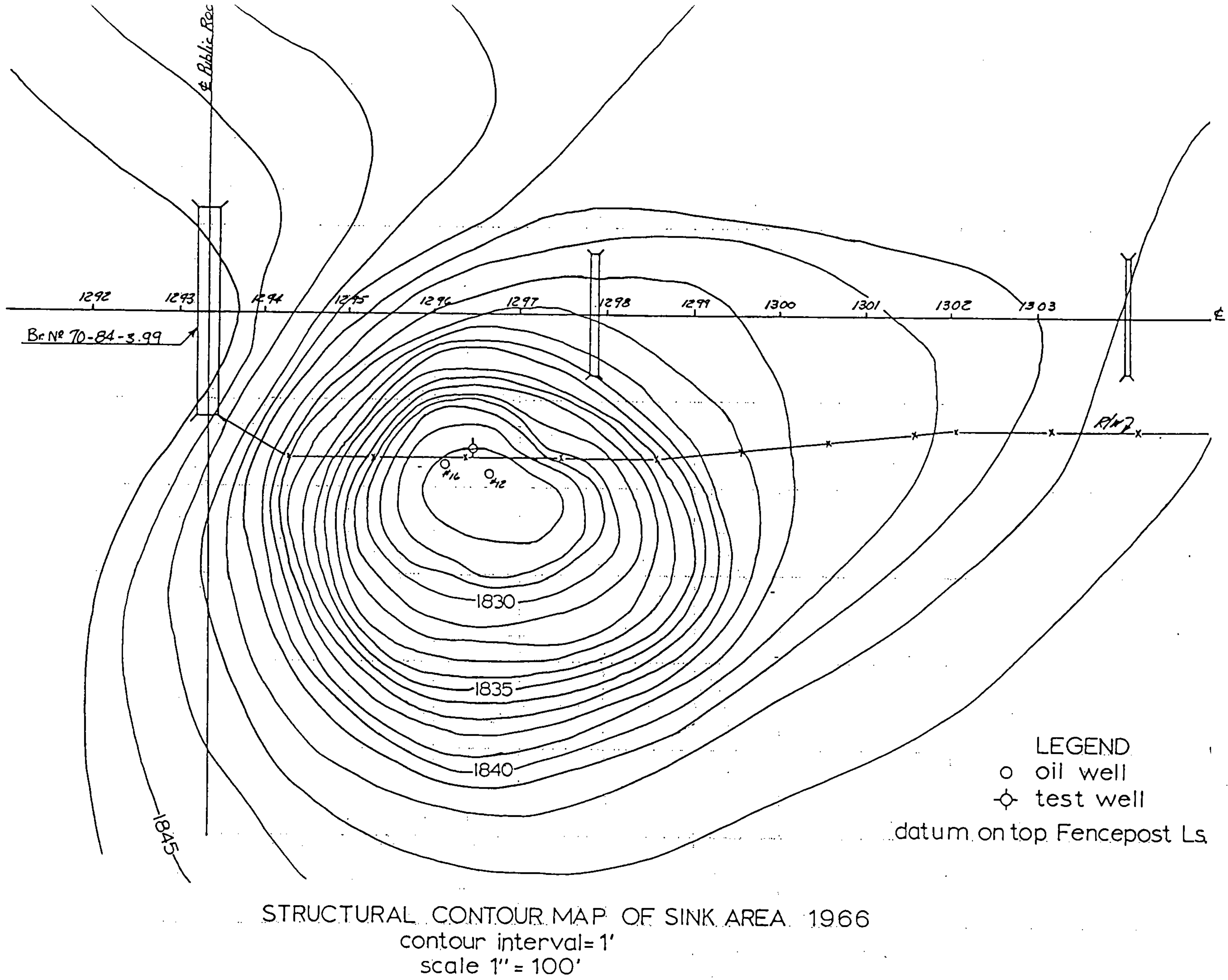

Figure 1: Structural contour map of Crawford Sink made soon after its discovery.

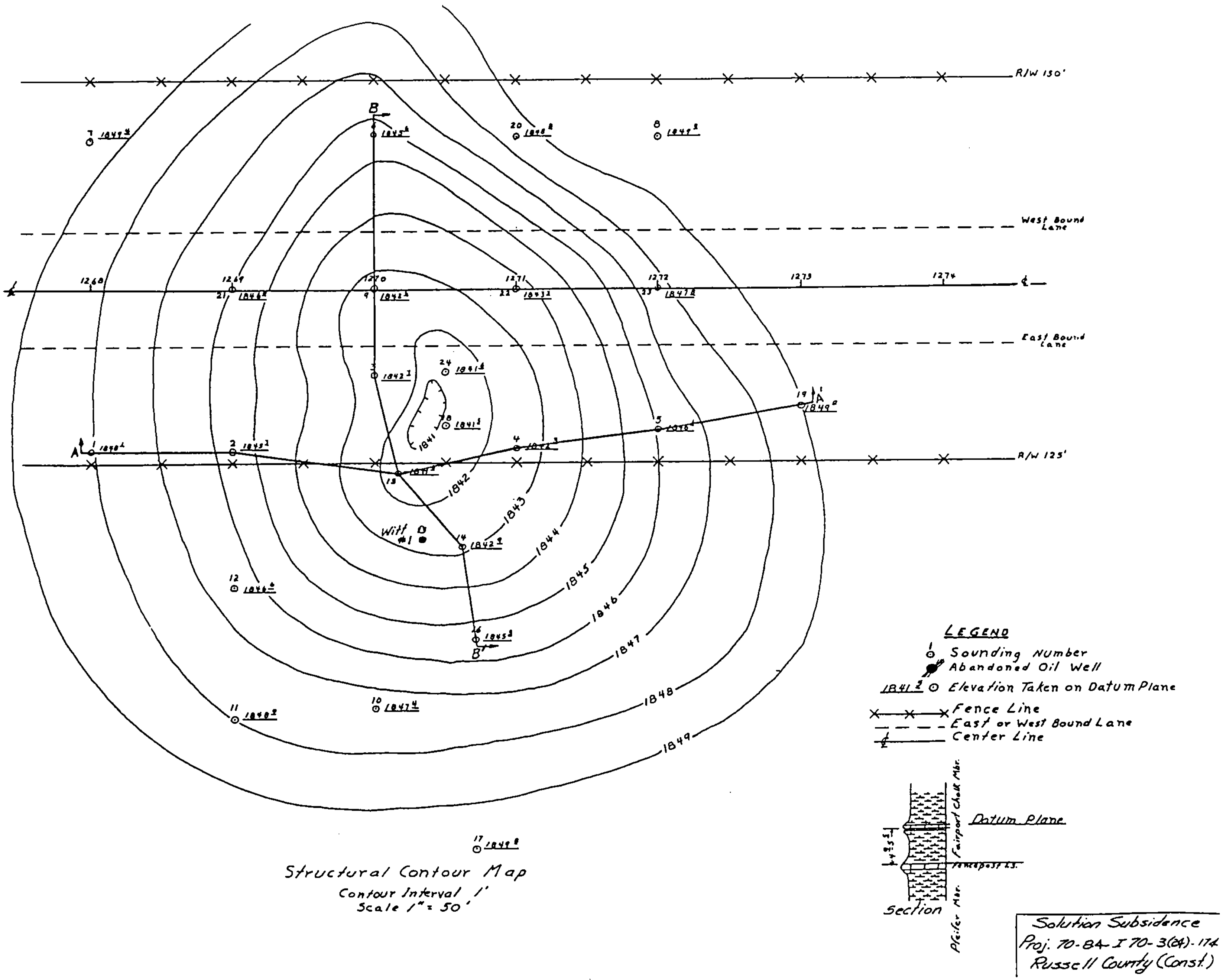

Figure 2: Structural contour map of Witt Sink from 1966.

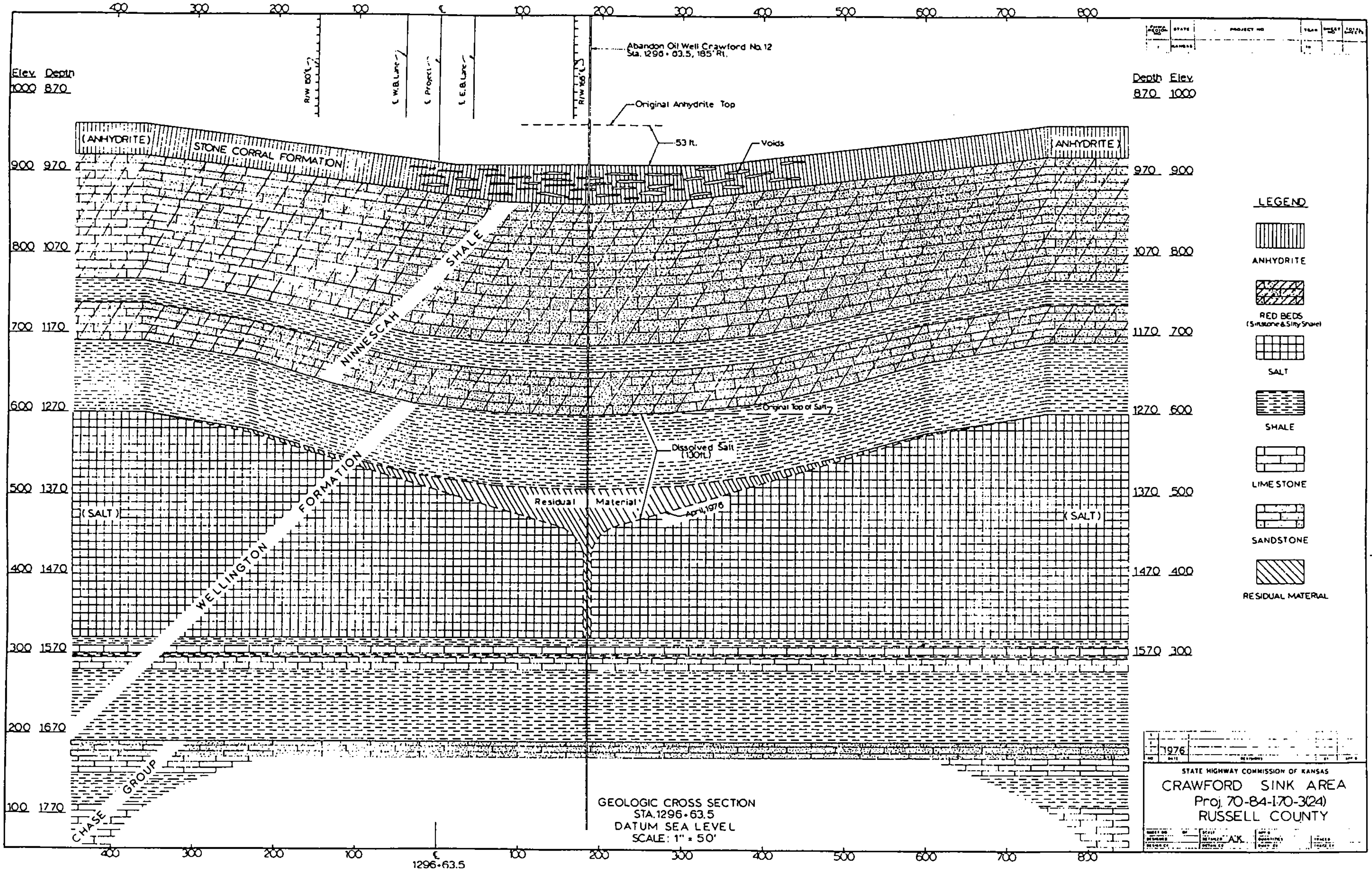

Figure 3: Cross-section of Crawford Sink, drawn after initial deep study in 1967.

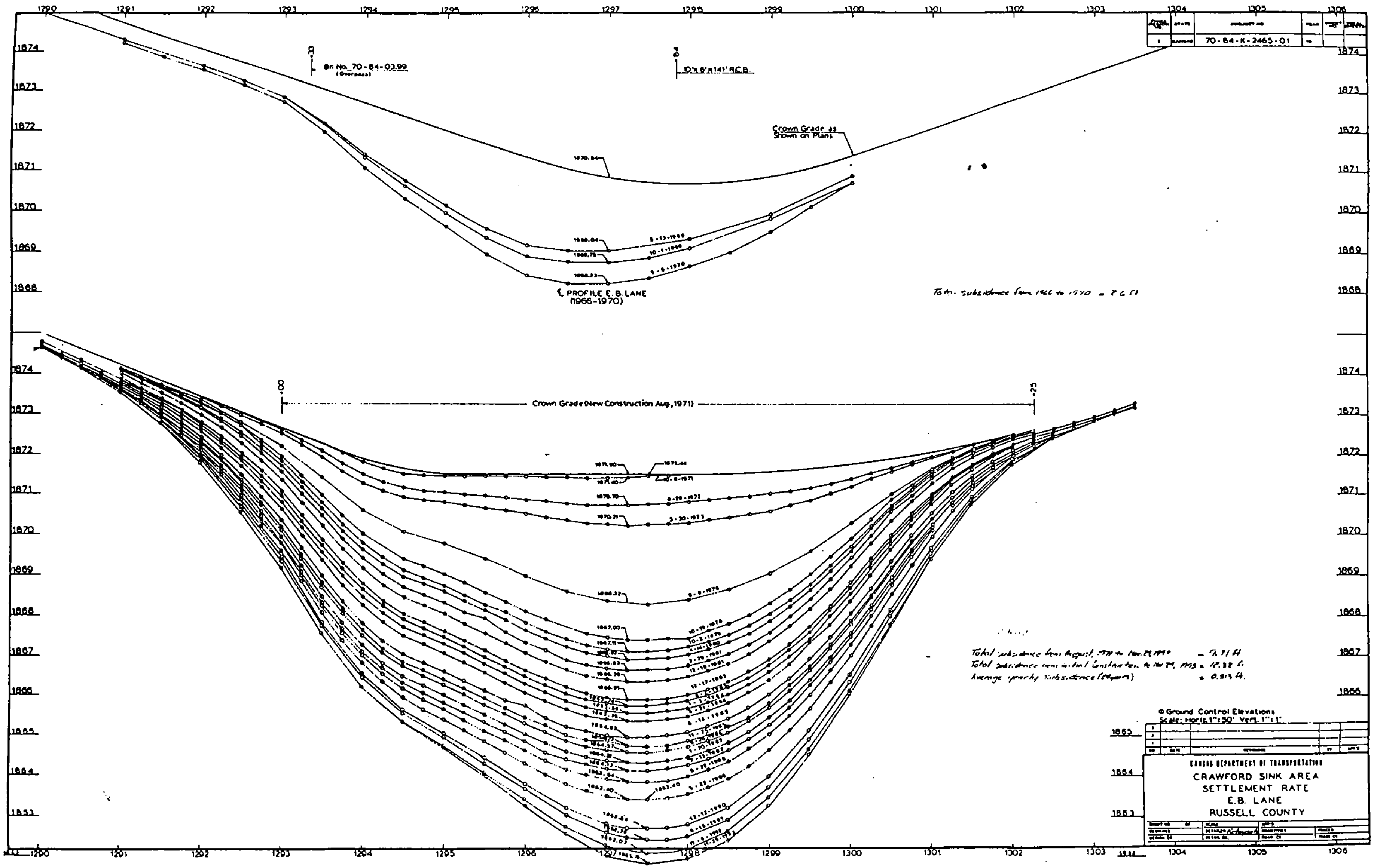

Figure 4: Profile of eastbound lanes of I-70 at the Crawford Sink. Upper graph shows settlement from 1966 to 1970. Lower graph covers from 1971, when lanes were regraded, to 1993. Total subsidence of the eastbound lanes during those 27 years was 12.3 feet.

Mine Subsidence Stabilization In Steeply Dipping Seams In the Canadian Rockies: A Project Overview

Presented by
Patrick E. Gallagher[1]

Abstract

CTL Engineering has been working on a project located in the Bituminous Coalfields of western Canada near the world famous Banff National Park. A large commercial/residential development has begun on a 5000-acre tract of land where a multiple seam abandoned coal mine is present. The coal was extensively mined from the mid-1800's until 1974 in four separate seams, all of which are steeply dipping (up to 85°). The workings pose a serious subsidence threat to the future buildings to be constructed in the development. Our mine stabilization program was designed to establish priority areas for stabilization and develop grout mixes that could overcome the steep dip of the seams.

The presentation of a paper at this conference will cover topics such as prioritization of the site, explorations of the proposed stabilization areas, evaluation criteria for the grouting patterns, mix designs, and borehole photography of the underground pumping operations. Other discussion include the regulatory review of the grouting and the process of permitting an underground injection program.

Project Description

The project is located 60 miles (100 km) due west of the City of Calgary, Alberta, Canada in the town of Canmore. The area surrounding the site is world renowned for its natural scenic beauty and popular travel destination of more than two million people annually. The land owners are presently planning to develop nearly 1900 acres (759 hectares) with residential, resort, and commercial communities. The entire property is underlain with abandoned underground coal mines in four separate seams. The mining method was room and pillar with some second mining encountered sporadically throughout the property. The geology is extremely complicated with folded, faulted, and steeply inclined sedimentary deposits consisting of interbedded sandstone, shales, coals and limestones.

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Fortunately, the past mine workings were well documented with extensive surveys and very detailed maps. The techniques employed by the miners to overcome near vertical dip angles are very impressive including hand augering, blasting and shoveling the coal on ladders that were laid on the mine floor for some 2,500 feet (762 m). The seam thickness' varied from 6 to 9 feet (1.83 to 2.74 m) typically with a limestone roof and the overburden consisted of a soil horizon averaging 20 feet (6.1 m) and a maximum depth to mine level of 900 feet (274 m). Dip angles varied from 25° to 85° and the mine floor was a weathered clayshale.

Risk Assessment and Regulatory Review

The first phase of the proposed development included 375 residential home sites and all of the infrastructure to support the construction of the homes. Utilities, roadways, wildlife crossings and various right-of-ways had to be included in our assessment of stabilization priorities in addition to the residential structures. The risk assessment evaluated the following criteria:

1. Depth of mine workings
2. Void height
3. Proposed land use
4. Geologic conditions
5. Extraction ratio / presence of pillaring
6. Width of entries and Pillar sizes

Giving consideration to the evaluation criteria; a plan was developed to stabilize high risk areas such as cropline features where sinkholes were present, areas where utilities were to cross mine workings within 100 feet of the void, and main access roadways. A High Risk Area was designated where the overburden to void height ration was less than 10 (i.e. a 10 foot (3.05 m) void at 100 feet (30.5 m) in depth). These areas posed the most potential for surfaces displacements that would result in severe damage. Secondly, Medium risk zones were determined to be non-residential areas where the overburden to void height ratio was greater than 10 but less than 30. These areas were investigated further to determine the areal extent of the workings and the proposed land use in order to evaluate it stabilization was required. Finally, Low Risk Zones were designated as areas where the overburden to void height ratio exceeded 30. Table 1 summarizes the evaluation criteria and potential impacts on the proposed development features.

Unlike the abandoned mine programs in the United States, the Province of Alberta, Canada and the Town of Canmore regulates any activity being conducted in abandoned mine areas. Figure 1 is an exhibit from the Town of Canmore regulations that identify the criteria for determining the various constraint zones near surface openings. Figure 2 is a similar exhibit from the regulations where high constraint zones are determined above mine workings. Figure 3 identifies medium constraint zones above mined areas. Each of these exhibits is used as guidelines to issue building permits for new developments within the Town of Canmore.

Stabilization Program

More than 300 exploratory borings were conducted in order to substantiate the conditions that exist throughout the development and refine the areas requiring stabilization. Following the subsurface exploration phase, it was decided that conventional cementitious grout materials would be injected into the mine workings to provide full roof contact support in the voided areas. Two types of materials were proposed to be used for the grouting, a high slump and low strength cement and flyash mix was designed to be used as production grout and a low slump concrete mix was designed as a barrier material. Flyash and cement were readily available from a local concrete plant as were various admixtures such as accelerators and plasticizer.

Three high priority areas were identified for stabilization during the first phase of development. The first area was the main access roadway leading to the 375 home sites where it traversed the cropline and some relatively shallow workings. The dip in this area approached 55°, the void height was 9 feet (2.74 m) and the workings were within 20 feet (6.10 m) of the surface. Figure 4 is the as-built plan of the grout stabilization that was completed along the main access road. 425 cubic yards (325 cu. Meters) of grout was injected into the void through 14 six inch boreholes. This volume of material exceeded the estimated volume by 22% which was a result of grout flow down dip. A down dip barrier of low slump concrete was installed to control the loss of grout but some bypass still occurred.

The second area that was grouted was a series of 3 drift entries which were open at the ground surface and were inclined at a dip angle of 35°. These entries were backfilled from the surface through a tremie pipe installed to the bottom of the entry. A total of 560 cu. yards (736 cu. meters) of grout was placed into the three entries. The third area was along an emergency access road where the road crossed over some relatively shallow workings. A conventional grout injection plan was developed and due to the presence of a localized syncline in the bedrock which resulted in flat lying strata. Figure 5 depicts the location of the injection holes and grout quantities that were located along the roadway centerline. During each grouting phase a borehole video camera was lowered into surrounding monitoring holes to document grout flows and direction of the workings.

Summary Discussion

Controlling material constituents, flowability and pattern of injection are the critical elements in assuring that the grout does not progress too far from the area to be stabilized. Appendix A includes compressive strength results of typical grout mixes from the project. We were encouraged that conventional stabilization techniques could be successfully used in steeply dipping seams with some precautions:

1. Batch pumping of not more than 50 cu. yds. (65 cu. meters) with each hour
2. Use of concrete bulkheads to confine down dip migration of the grout.

3. Acknowledge that over grouting by at least 125% can be expected.
4. Begin grouting operations at the lowest elevation of the mine and proceed up dip to ensure full roof contact.
5. Fully understand the mining pattern and geologic conditions. We found that the use of down dip barrier pillars or ribs is a preferred initiation point for the grouting operation.

Steeply dipping room and pillar mines can be successfully stabilized by use of conventional grouting techniques provided a detailed investigation of the controlling geologic conditions has been completed.

Acknowledgments

This author would like to acknowledge his development partners in this project as Norwest Resource Consultants, Ltd., Suite 400, 205 9th Avenue, S.E., Calgary, Alberta, Canada. Specifically Mr. Richard Dawson, Senior Geotechnical Engineer for Norwest, was the Chief Investigator and Mr. Gallagher was Senior Consultant to Norwest.

TABLE #1

UNDERMINING EVALUATION CRITERIA FOR POD 7/8

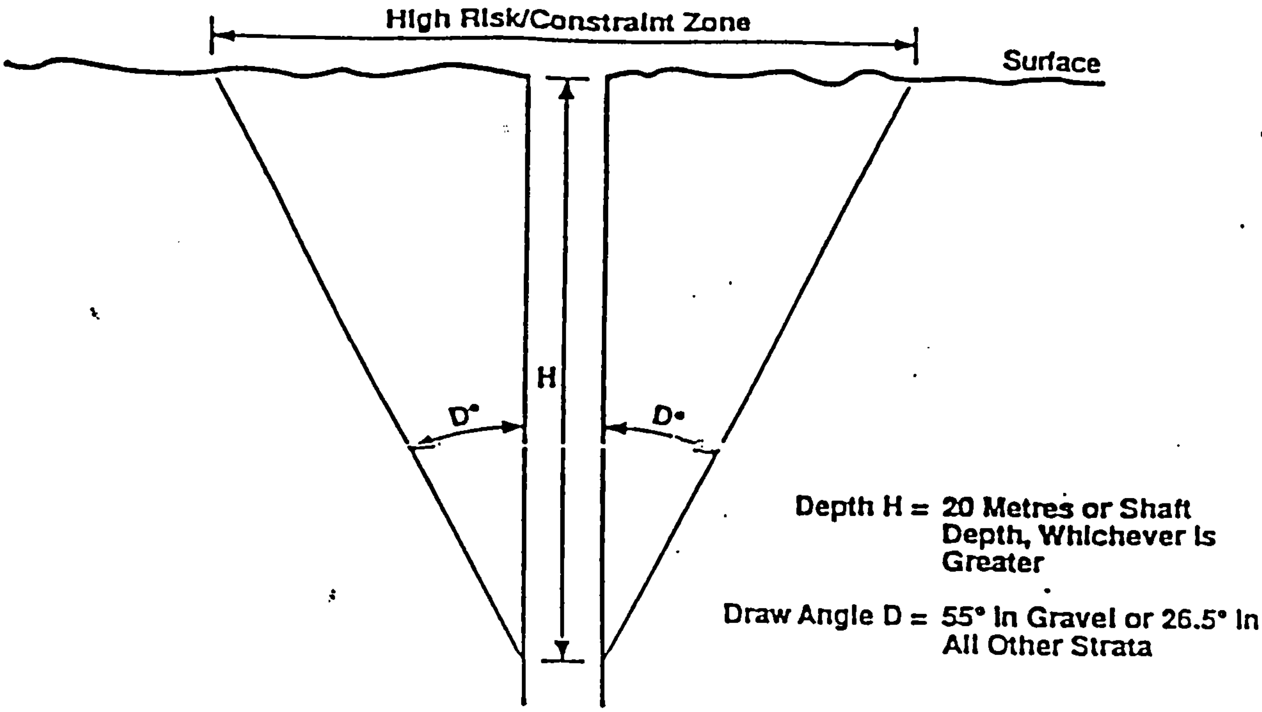
EXTENT OF UNDERMINING	MINE ROOF COLLAPSE POTENTIAL	BEDROCK HEIGHT TO EXTRACTION HEIGHT RATIO	SURFACE DISPLACEMENT POTENTIAL	POTENTIAL IMPACTS		
				ROADS	UTILITY CORRIDORS	STRUCTURES
NON-DEPILLARED AREAS/SINGLE DRIVAGES	Very Low to Medium	Less than 10	High to Medium	Sink holes, road surface potholing, high settlements, likely disruption of road use, safety hazard.	Severing of utility lines, over-tensioning of cables, likely disruption of service, safety hazard.	Major differential movements, foundation structural collapse, potential safety hazard.
		10 to 30	Medium to Low	Tension cracking, minor settlement, pavement potholing, unlikely disruption of road use.	Stressing service lines, sagging, possible disruption of services.	Medium settlements, some tension cracking, foundation movements.
		Over 30	Low to Very Low	Minor to negligible cracking, sagging, minor repairs required.	Minor to negligible stressing of service lines, unlikely disruption of service.	Minor to negligible settlements, undetectable foundation movements.
DEPILLARED AREAS	Medium to High	Less than 10	High	Sink holes, potholing, high settlements, likely disruption of road use, safety hazard.	Severing of lines, high tension stresses, disruption of services, safety hazard.	Major differential movements, foundation failure, structural collapse, potential safety hazard.
		10 to 30	Medium	Cracking, differential movements, potholing, medium settlements, possible disruption of road use.	Tensioning of lines, sagging, possible disruption of services.	Medium settlements, tension cracking, uncontrollable foundation movements, potential structural impacts.
		Over 30	Medium to Low	Cracking, sagging, repairs required.	Tensioning of lines, sagging, possible disruption of services.	Minor to medium settlement, potential foundation movements causing minor cracking.
SHAFTS / SLOPES TO SURFACE	Low to High	N/A	Low to High	Variable impact depending on site conditions at each shaft or slope. Very dangerous conditions can occur around surface features. Potential major safety hazard.		

- Mine Roof Collapse Potential: A qualitative measure of the potential for void failure within the mine workings. The main factors affecting mine roof collapse potential are depth, opening dimensions, support, strata quality, groundwater conditions, and the age of the workings. In general, non-depillared areas and single drivages have lower mine roof collapse potential than depillared areas because of generally lower void widths.

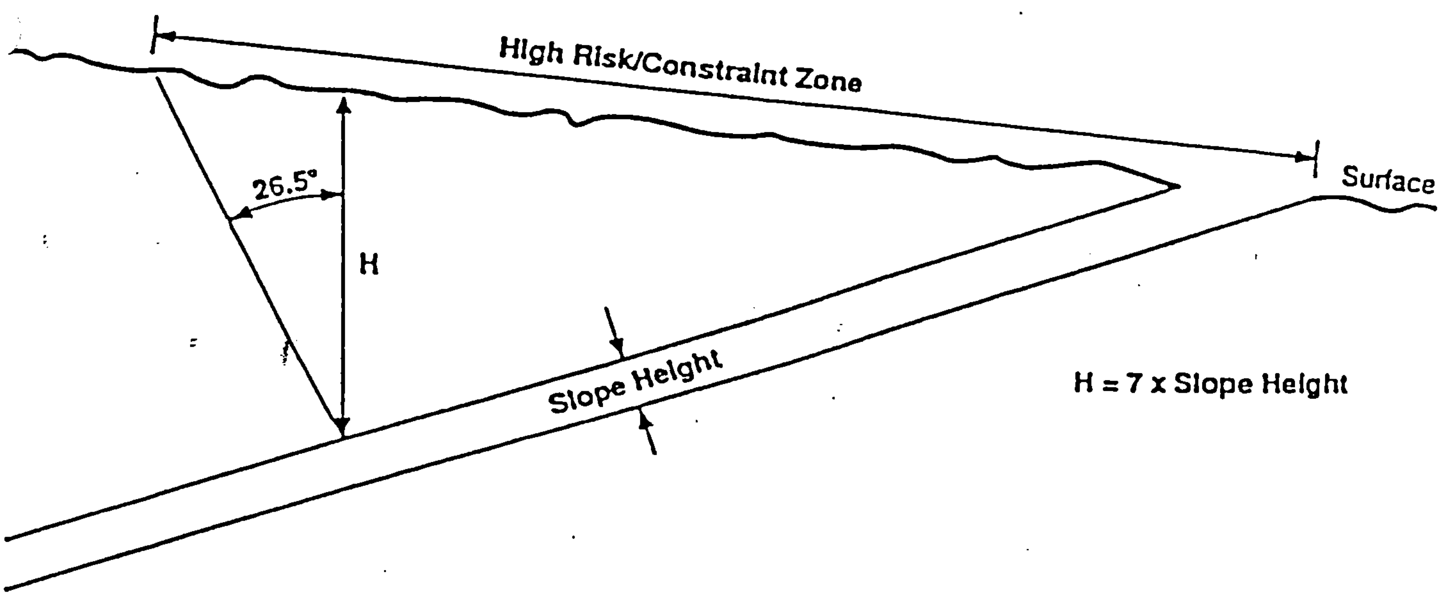
- Bedrock Height to Void Height Ratio: Ratio of bedrock thickness to extraction height. The ratio is measured in the vertical direction.

- Surface Displacement Potential: A qualitative measure of the potential for surface displacements that could affect roads, services, and structures. The main factors affecting surface displacement potential are bedrock height to extraction height ratio, opening dimensions, groundwater conditions, age of the workings, and strata quality. In general, a low rating implies minor movements that should be tolerable or insignificant should they occur and a high rating poses a safety hazard and necessitates mitigative measures. The impacts of a medium rating depend on whether a roadway, utility corridors or structure will be affected.

- Potential Impacts: A measure of the potential affects of undermining induced surface displacements on roads, utility corridors, and structures. These are descriptive assessments derived from the qualitative measures of mine roof collapse and surface displacement potential. The impacts represent potential damage should surface movements occur and providing that mitigation is not undertaken.



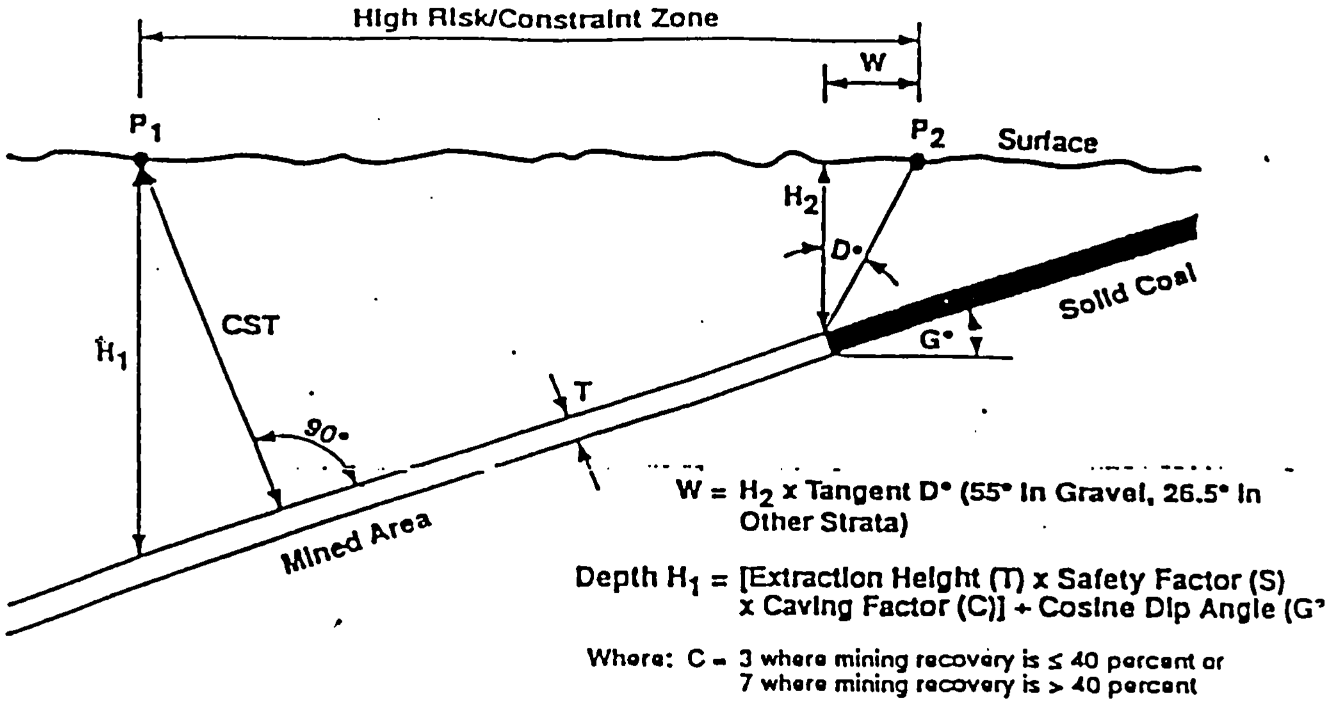
A. VERTICAL SHAFT



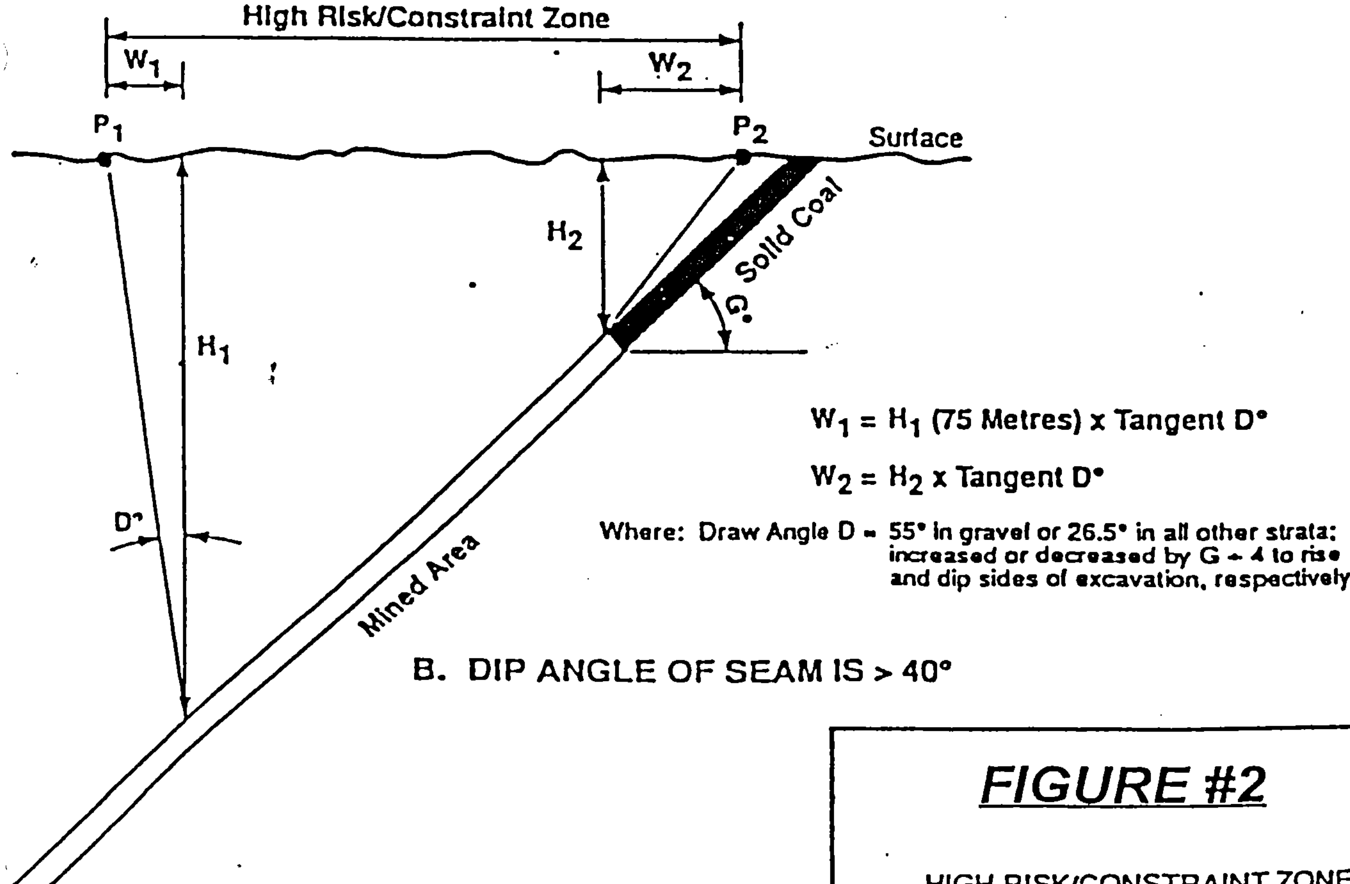
B. SLOPE OR INCLINED ACCESS

FIGURE #1

HIGH RISK/CONSTRAINT ZONE
EXTENT FOR SURFACE OPENINGS



A. DIP ANGLE OF SEAM IS ≤ 40°



B. DIP ANGLE OF SEAM IS > 40°

FIGURE #2

HIGH RISK/CONSTRAINT ZONE
EXTENT FOR UNDERMINED AREAS

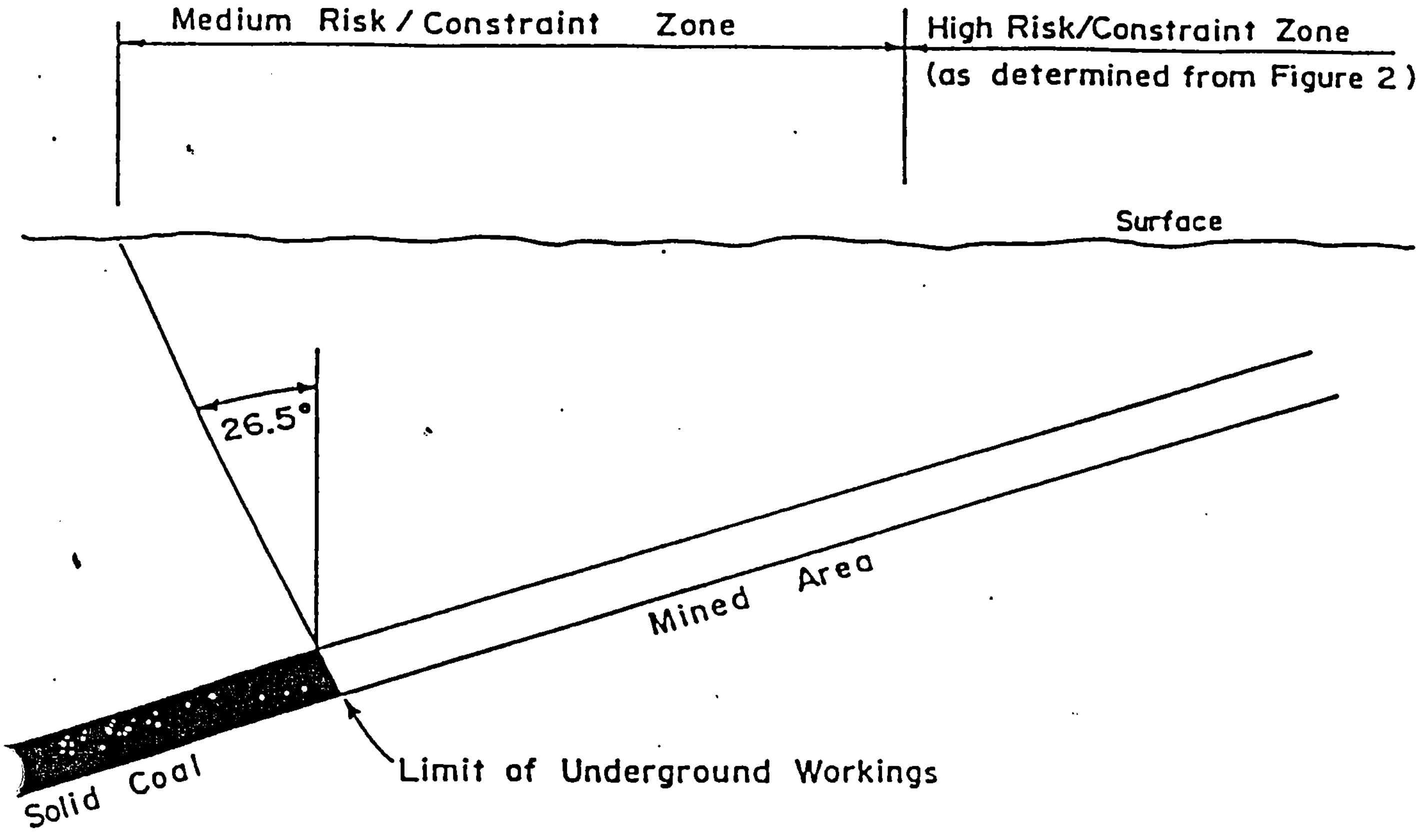


FIGURE #3

MEDIUM RISK/CONSTRAINT ZONE
EXTENT FOR UNDERMINED AREAS

FIGURE #4

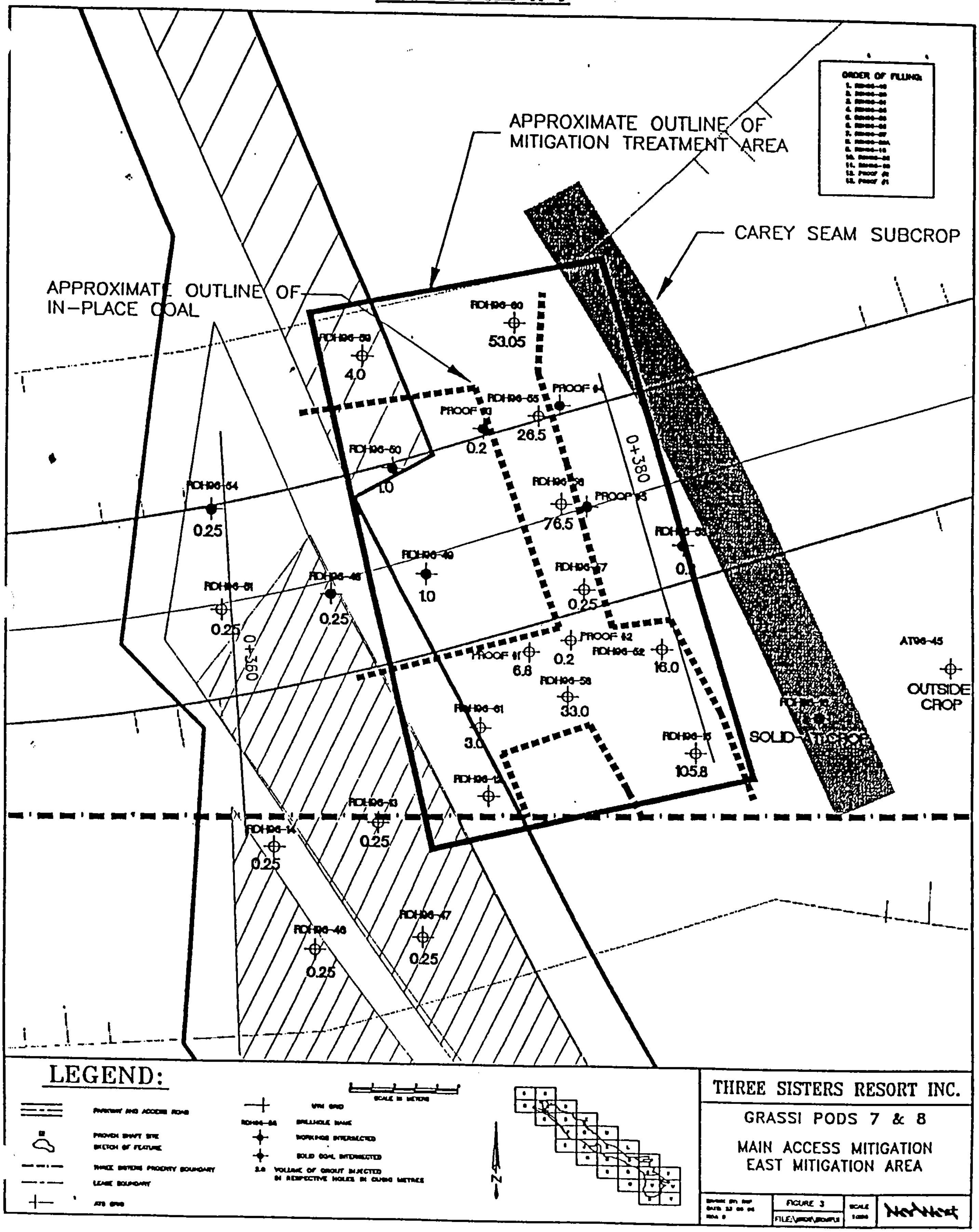
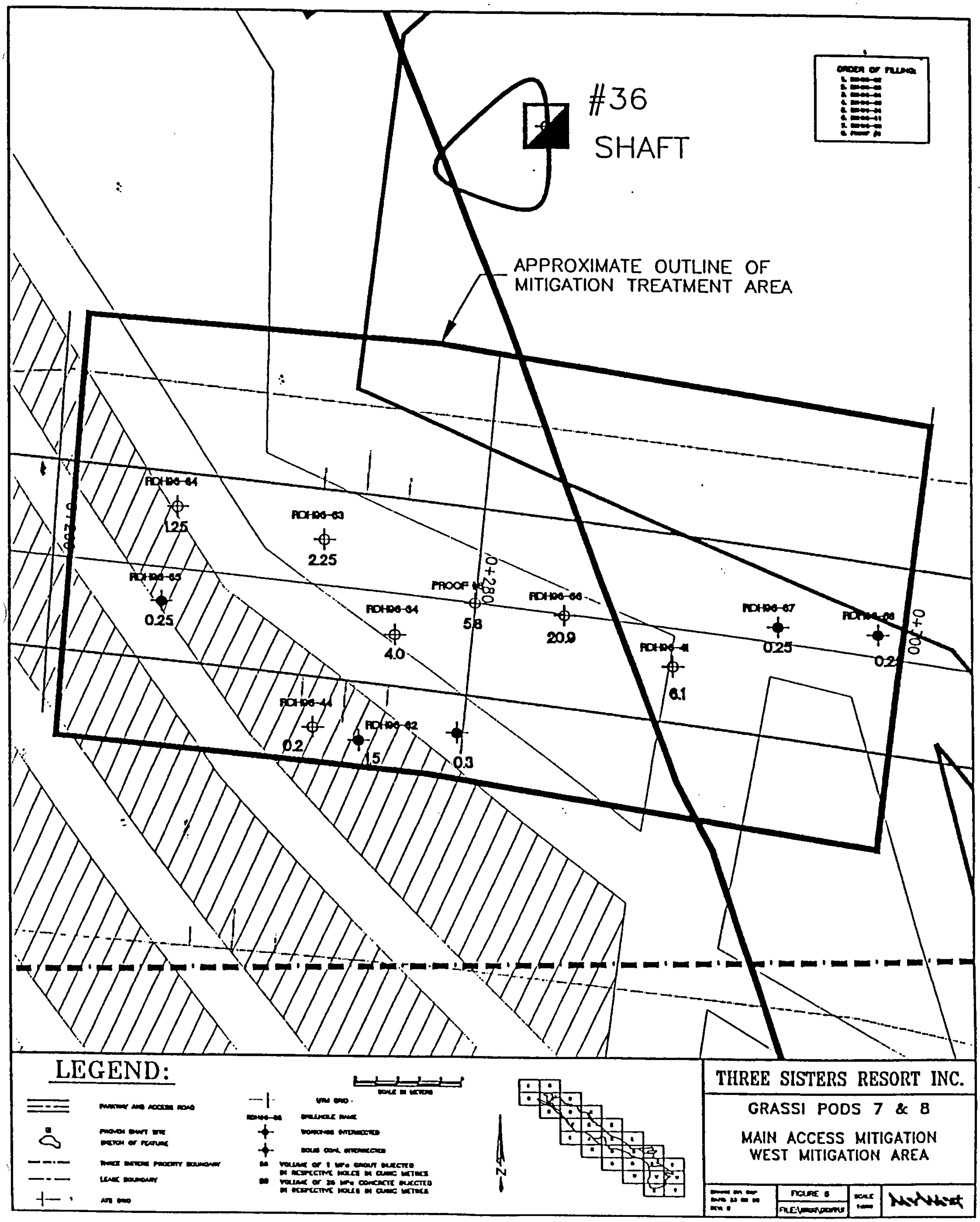

APPROXIMATE OUTLINE OF MITIGATION TREATMENT AREA
APPROXIMATE OUTLINE OF IN-PLACE COAL
CAREY SEAM SUBCROP
ORDER OF FILLING
RDH96-60
53.05
RDH96-59
4.0
PROOF 64
RDH96-55
PROOF 63
0.2
26.5
RDH96-50
1.0
0+380
RDH96-54
0.25
PROOF 65
76.5
RDH96-49
1.0
RDH96-57
0.25
RDH96-51
0.25
RDH96-48
0.25
0+360
PROOF 62
0.2
PROOF 61
6.6
RDH96-52
16.0
RDH96-58
33.0
AT96-45
OUTSIDE CROP
RDH96-61
3.0
SOLID-AT-CROP
105.8
RDH96-12
RDH96-13
0.25
RDH96-14
0.25
RDH96-47
0.25
RDH96-46
0.25
LEGEND:
SCALE IN METRES
THREE SISTERS RESORT INC.
GRASSI PODS 7 & 8
MAIN ACCESS MITIGATION
EAST MITIGATION AREA
FIGURE 3
N

FIGURE #5


#36
SHAFT
APPROXIMATE OUTLINE OF
MITIGATION TREATMENT AREA
1.25
2.25
0.25
PROOF
0+280
5.8
20.9
4.0
0.25
0.2
0+700
6.1
0.2
1.5
0.3
LEGEND:
THREE SISTERS RESORT INC.
GRASSI PODS 7 & 8
MAIN ACCESS MITIGATION
WEST MITIGATION AREA

APPENDIX A

CURTIS ENGINEERING ASSOCIATES LTD.

1, 820 - 28 Street NE, Calgary, AB T2A 6K1

CONCRETE TEST REPORT

CERTIFIED CONCRETE TESTING LABORATORY

To: NORWEST MINE SERVICES LTD.
400 205 9 AVENUE SW
CALGARY, AB
T2G 0R8

File No: (C.E.A.) CM 954-1
Client: NORWEST MINE SERVICES LTD.(2)
CC: BURNCO ROCK PRODUCTS

Attn: RICHARD DAWSON

Project: BLOCK 6, MINE FILL, PHASE II
THREE SISTERS MINE , CANMORE

Suppliers Ticket Data

Cement Type: 50
Admixtures:
Max. Agg. Size: 20 mm
Slump: mm
Air Content: %
Comp. Strength: @ 28 Days 25 MPa
Supplier: 3 BURNCO ROCK PRODUCTS
Mix No: UNKNOWN Batch Time:
Truck No: Ticket No:
Load Vol. (m³) Cum. Vol. (m³)

Test Data

Test Location: MAIN ACCESS: POD 7 & 8
Date Cast: 96.Sep.06 Date Rec'd: 96.Sep.09
Time Cast: Cast By: CLIENT RAY
Air Temp: °C Conc. Temp. °C
Init. Curing Temp: °C (Max.) °C (Min.)
Slump: mm Air: %
Type of Concrete:
Unit Wt. kg/m³ Type of Mold:

Test Number	Sample Number	Age Days	Average Height mm	Average Diameter mm	Cross Sectional Area mm²	Maximum Load kN	Compressive Strength MPa	Type of Failure
6	A	7	200.0	100.0	7850	161	20.5	
6	B	28	200.0	100.0	7850	283	36.1	C
6	C	28	200.0	100.0	7850	275	35.0	C

Remarks:

TYPE OF FAILURE

C CONICAL
D DIAGONAL SHEAR
V VERTICAL SPLITTING
E END FAILURE
O OTHER

96.Oct.18 Page 1 END OF REPORT

Concrete samples cured and tested in accordance with C.S.A. standards for that portion of the testing performed by this Company.

Certified By: V. Kuzbin

DUPLICATE

CONCRETE TEST REPORT

CERTIFIED CONCRETE TESTING LABORATORY

CURTIS ENGINEERING ASSOCIATES LTD.

1, 820 - 28 Street NE, Calgary, AB T2A 6K1

To: NORWEST MINE SERVICES LTD.
400 205 9 AVENUE SW
CALGARY, AB
T2G 0R8

File No: (CEA) CM 954-1
Client: NORWEST MINE SERVICES LTD.(2)
CC: BURNCO ROCK PRODUCTS

Attn: RICHARD DAWSON

Project: BLOCK 6, MINE FILL, PHASE II
THREE SISTERS MINE , CANMORE

Suppliers Ticket Data

Cement Type: 50
Admixtures:
Max. Agg. Size: 10 mm
Slump: 150+/-50 mm
Air Content: %
Comp. Strength: @ 28 Days 1 MPa
Supplier: 3 BURNCO ROCK PRODUCTS
Mix No: 45 Batch Time: 10:20
Truck No: Ticket No:
Load Vol. (m³) Cum. Vol. (m³)

Test Data

Test Location: MAIN ACCESS: POD 7 & 8
Date Cast: 96.Aug.30 Date Rec'd: 96.Sep.03
Time Cast: 11:00 Cast By: CLIENT RAY
Air Temp: 22 °C Conc. Temp. 19 °C
Init. Curing Temp: °C (Max.) °C (Min.)
Slump: 200 mm Air: %
Type of Concrete:
Unit Wt. kg/m³ Type of Mold: PLASTIC

Test Number	Sample Number	Age Days	Average Height mm	Average Diameter mm	Cross Sectional Area mm²	Maximum Load kN	Compressive Strength MPa	Type of Failure
4	A	7	200.0	100.0	7850	9	1.1	
4	B	28	200.0	100.0	7850	12	1.5	C

Remarks: .SPECIFIED SLUMP - 150mm +/- 30mm

TYPE OF FAILURE

C CONICAL
D DIAGONAL SHEAR
V VERTICAL SPLITTING
E END FAILURE
O OTHER

96.Oct.18 Page 1 END OF REPORT

Concrete samples cured and tested in accordance with C.S.A. standards for that portion of the testing performed by this Company.

Certified By: V. Nyfern

Fly Ash Use in Pressurized Grout Remote Backfilling of Abandoned Underground Mines in North Dakota[1]

By: William E. Dodd[2]

ABSTRACT

The Abandoned Mine Lands (AML) Division of the North Dakota Public Service Commission (PSC) has been charged with the reclamation of hazardous abandoned coal mines since 1981. More than 85 primary reclamation projects, at a cost of over $23 million, have been completed in North Dakota. Pressurized grout remote backfilling is a technique for stabilizing hazardous collapsing underground mines. In this technique, a cementitious grout is pumped through cased drill holes directly into mine cavities to fill them and thereby stabilize the surface from collapse. In 1995 the North Dakota State Health Department approved the use of grout formulations containing fly ash. This approval was based on results of a comprehensive grout testing research project funded by the PSC. Fly ash replaced some of the cement in the grout formulation. Fly ash is cheaper than cement and it also improves flowability of the grout. The AML Division estimates an approximate $500,000, or 18%, reduction in the cost of pressurized grout remote backfilling projects since 1995 resultant from the use of fly ash as a grout component.

Additional Key Words: Underground Mine Reclamation, Coal Combustion Byproducts

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Introduction

There are more than 600 abandoned coal mines in North Dakota. Most of these are abandoned underground mines. As these abandoned underground mines have deteriorated with time, deep collapse features, or sinkholes, have surfaced in many areas. These features are very dangerous, especially when they occur at or near residential and commercial areas and public roads. The Abandoned Mine Lands (AML) Division of the North Dakota Public Service Commission (PSC) has been using remote backfilling methods in an attempt to prevent mine subsidence in high-use areas since the early 1980's.

Gravity fill remote backfilling was utilized until 1990. In this method, slurry, usually consisting principally of sand and water, was poured down drilled holes directly into the underground mined workings. Results of gravity fill remote backfilling were often unsatisfactory because the slurry could not penetrate all void areas if the mine was already partially collapsed. In addition, the slurry was not cohesive and tended to flow, to be washed away, or to settle as the water dissipated.

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[1] Presented at the KDOT 2000 Abandoned Underground Mine Workshop, Kansas City, MO, April 25-27, 2000.

[2] William E. Dodd is an Environmental Scientist and Project Manger, North Dakota Public Service Commission, Bismarck, ND.

Since 1991 pressurized grout remote backfilling has been used in North Dakota for stabilizing hazardous collapsing underground mines. In this technique, a cementitious grout is pumped through cased drill holes directly into mine cavities. This method is effective for stabilizing the surface from underground mine subsidence, especially when mined workings have begun to collapse.

One of the drawbacks of pressurized grout remote backfilling was its high cost, mainly due to the high cost of Portland Cement. In the mid-1990's, the AML Division began looking for a more cost effective, yet environmentally safe grout formulation. In 1995, a comprehensive grout testing research project determined that flyash from specific sources readily available in North Dakota could be used to replace some of the cement in the grout mix. This research yielded a grout formulation that is cheaper and has better handling characteristics, yet is relatively safe.

Part 1 – Fly Ash

Fly ash is a solid fuel combustion residue collected by filtration of the smoke discharged by coal fired power plants. Power plants in the US produce around 100 million tons of fly ash annually.

Fly ash is about 80-90% composed of glass formed from molten clays, shales, limestone, and dolomite. These small spherical particles combine with calcium hydroxide to form calcium silicate hydrate, the principal binder of cement. Fly ash is classified by its cementitious properties by the American Society for Testing and Materials (ASTM).

Fly ash is a pozzolan. Pozzolans are materials that form cement-like compounds when mixed with lime and water. Fly ash is somewhat similar to volcanic ash used to produce the earliest cements about 2300 years ago near the Italian town of Pozzuoli. Although most of the fly ash produced in the US is disposed of as a waste product in landfills and impoundments, it has many potentially beneficial uses.

Fly ash is used in concrete for road construction, masonry, and in controlled density fills for residential sub-footings. It can also be used as filler in asphalt roofing products and in composites such as ceramics and plastics. Fly ash is sometimes used as a soil amendment and in production of potting soil. Finally, fly ash is used in mine reclamation projects to fill surface and underground mines and to treat acid mine drainage and soils.

Part 2 - Coal Mining and Abandoned Mine Reclamation in North Dakota

North Dakota has the largest reserves of lignite coal in the US. Lignite is a low-grade, relatively soft coal. The lignite bearing area in ND covers about 28,000 square miles (Burr 1954). Lignite has been mined commercially in North Dakota since the 1870's. Underground mining was predominant in North Dakota until the 1930's. The number of commercial lignite mines in North Dakota peaked at about 320 in 1940 (Dahlberg et al 1984).

Lignite markets changed primarily to electric generation in the late 1940's as household demand began switching to fuel oil and natural gas. In the 1960's, huge "mine-mouth" electrical generating plants were constructed in North Dakota. A large coal gasification plant (the only one in North America) was constructed near Beulah, North Dakota in the 1970's.

In 1980, North Dakota compiled an inventory of surface and underground coal mine sites in the state abandoned prior to 1977. This inventory categorized 616 abandoned mine land (AML) sites in ND. These sites were prioritized with regard to their danger to public health, safety, general welfare, and property. Many sites have been added to this inventory and Wald and Beechie, 1996, estimated that there may be more than 2000 AML sites in the state. Often new sites are added as landowners call to report new sinkholes resulting from collapse of mined workings.

North Dakota's AML Reclamation Program was authorized in 1981. Program funding comes from a ten cent per ton production tax on lignite coal mined within the State. Currently State lignite production is about thirty million tons per year. Thus, approximately three million dollars is paid annually into the AML Fund, administered by the Office of Surface Mining Reclamation and Enforcement (OSMRE), Department of Interior. About half of this money, $1.5 million, is returned to the State of North Dakota to eliminate existing and potential public hazards resulting from abandoned surface and underground coal mines.

Since 1981, more than 85 primary reclamation projects have been completed in North Dakota at a cost of over $23 million. In addition, several smaller maintenance and emergency projects have been conducted. These projects have included backfilling dangerous surface mine pits, extinguishing mine fires, filling dangerous sinkholes resulting from collapse of underground mines, and remote backfilling to prevent collapse of underground mines beneath homes, buildings and roads. Reclamation projects are designed in-house by AML Division project managers and are conducted by contractors who are selected by competitive bidding.

Remote backfilling of North Dakota underground mined workings in the 1980's was usually accomplished by gravity feed methods in which sand/water slurry was poured down drilled holes into the mine. This method was somewhat successful if the underground mined workings were intact. If they were in a state of collapse, the gravity fed slurry would not penetrate the collapsed soil materials and significant void areas could be left to collapse in the future. Also, the sand/water slurry was not cohesive and could be washed away if there was water movement in the mine.

Most of the abandoned underground mines in North Dakota are at least partially collapsed. In the late 1980's the North Dakota AML Division made a transition from gravity fill to pressurized grout remote backfilling. In this technique, a cementitious grout is pumped through cased drill holes directly into mine cavities to fill them and thereby stabilize the surface from collapse. Grout pumped under pressures from 0-400 psi can usually penetrate rubblized soil materials adequately. In addition, after the cementitious grout hardens it will not flow or wash away.

Pressurized grout remote backfilling is effective but is also costly, often tens or even hundreds of thousands of dollars per acre. However, it is relatively cheap compared to "daylighting," or excavating down to the mined workings and backfilling with dirt. Pressurized grout remote backfilling is used in North Dakota to stabilize high-use properties such as residential and commercial areas and public roads.

Part 3 - Fly Ash-Grout Use in North Dakota

The grout mix presently in use for North Dakota reclamation projects was developed as the result of a comprehensive grout testing research project funded by the North Dakota Public Service Commission. This research project is described in a paper entitled, Flyash Grout Testing In a Simulated Wet Mine Environment by Wald and Beechie, 1996. Prior to this research, the North Dakota State Department of Health had not allowed the use of fly ash-grout for reclamation of underground mines containing water.

The fly ash-grout testing project compared 23 different grout formulations with varying amounts and sources of fly ash, cement, sand, water and superplasticizer. This fly ash grout-testing project was developed to determine the most cost effective, environmentally safe grout material available for use in reclamation of dry and wet underground mines. Grout formulations were evaluated for flowablility, pumpability, cohesiveness (non-segregation during pumping), compressive strength, and leaching potential in water. Leaching potential was determined by comparing leachate from each formulation to North Dakota's drinking water standards.

Results of this project indicated that two sources of fly ash were superior and a grout formulation was developed using these sources: Great River Energy's Coal Creek Station, Underwood, ND, and Basin Electric's Antelope Valley Station (AVS), Beulah, ND. The selected grout formulation contains 100 pounds cement, 600 pounds of fly ash, 70 ounces superplasticizer, approximately 2200 pounds of sand, and 65 gallons of water, per cubic yard. The North Dakota State Health Department approved the use of this formulation in 1995 with the stipulation that only Coal Creek or AVS Fly Ash could be used. The Health Department preferred Coal Creek Fly Ash because of its superior leachate characteristics, but AVS Fly Ash was also approved as an acceptable alternative.

Part 4 – Benefits of Fly Ash-Grout

Fly ash replaced some of the more expensive cement in the grout mixture, thereby reducing the cost per cubic yard. The AML Division estimates a nearly $500,000, or 18%, reduction in the cost of pressurized grout remote backfilling projects since 1995 as a result of the use of fly ash (Table 1).

When used with cement, fly ash improves flowability and increases compressive strength. It improves flowability because the spherical particles act like ball bearings. This allows the grout to move more freely and the small particle size promotes better filling of voids. The cementitious properties of fly ash increase compressive strength. Contract specifications for grouting projects in North Dakota presently require that the unconfined compressive strength of grout be at least 150 psi at 28 days. Use of fly ash also reduces shrinkage and slows set-up time, an important factor if grout pumping must be interrupted for a few hours. Another important reason for using fly ash is recycling: every ton of fly ash used beneficially is one not disposed in a landfill.

Fly ash can potentially pose environmental and health risks. It contains trace amounts of several toxic elements including boron, molybdenum, selenium, and arsenic. These elements could contaminate soil and water. Portland cement also contains these elements and they can occur naturally in soil and water. If used responsibly, fly ash is a safe product and can be used safely with very limited chances of polluting soils or water.

After grout containing fly ash hardens it is fairly inert. Research conducted by North Dakota Public Service Commission (Wald and Beechie 1996) found that grout mixes using fly ash often leached lower concentrations of trace minerals than cement-only grout. This research also indicated that, depending on the source of fly ash, leachate from hardened grout could meet safe drinking water standards for heavy metal concentrations.

Summary and Conclusions

Fly ash will continue to be produced as long as coal-fired electricity is generated. Coal is an abundant and relatively cheap resource. Although concerns about fly ash use and disposal are valid, some environmental groups have sensationalized these concerns. These groups are lobbying the US Environmental Protection Agency (EPA) to classify fly ash as a hazardous waste. This could severely limit fly ash recycling and its beneficial uses and result in higher energy costs.

The use of fly ash as a grout component has resulted in improved performance and significant cost savings in pressurized grout remote backfilling projects in North Dakota. Research conducted in North Dakota indicates that sources differ markedly in chemistry and performance of their fly ash. These differences result from properties of the coal itself and the method of coal processing and combustion. A responsible user should thoroughly test fly ash from each potential source to ensure that it is appropriate for its intended use.

The North Dakota Public Service Commission, Abandoned Mine Lands Division intends to continue using fly ash grout in its pressurized grout remote backfilling projects. It remains in close consultation with the North Dakota Department of Health and we will jointly continue to monitor the performance and environmental aspects of the use of fly ash grout in the future.

Literature Cited

Burr, Alex C. 1954. The Mineral Resources of North Dakota. North Dakota Research Foundation Bulletin No. 8. Bismarck, ND

Dahlberg, J.C., J. Kjos, and M. Schriener, 1984. Lignite Use and Development of the Lignite Industry in North Dakota. DSKS Research, J.V.

Meuchel, Donavon. Earth, Energy and Water Systems, New Salem, ND. Personal Communication. February 7, 2000.

Wald, Steve and Bruce Beechie. 1996. Flyash Grout Testing in a Simulated Wet Mine Environment. Proceedings of the 18th Annual Conference of the Association of Abandoned Mine Lands Programs. Kalispell, Montana, September 15-18, 1996.

Figure 1
Fly Ash Use in Pressurized Grout Remote Backfill Projects Since 1995
North Dakota Public Service Commission
Abandoned Mine Lands Division

Background

On April 26, 1995, the Public Service Commission (PSC) received approval from the North Dakota Department of Health to use specific grout formulations containing fly ash. This approval was based on the result of a PSC-funded research project comparing physical and chemical characteristics of 23 grout formulations, This allowed the PSC to replace its previously approved formulation, containing 400 lbs of cement and no fly ash, with one containing 100 lbs cement and 600 lbs. fly ash. The addition of fly ash to the grout improved its flowability and reduced its cost. The AML Division estimates a \$500,000, or 18%, reduction in the cost of grouting projects since 1995 as a result of the use of fly ash.

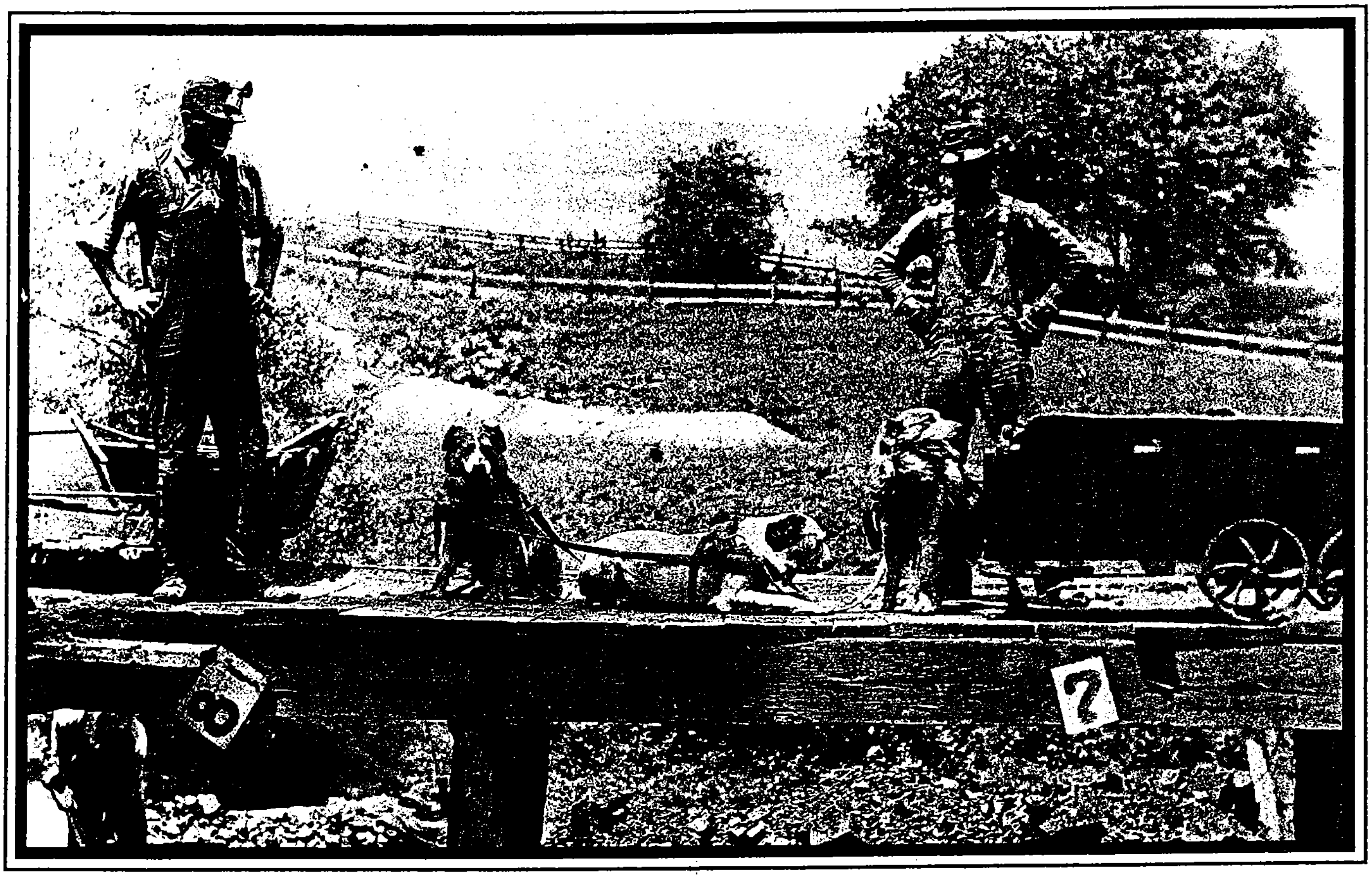
Year	Site	Location	Grout Vol. (cyd)	Flyash (lbs)	Flyash (tons)	Contractor	Flyash Supplier	Project Cost	Est. Savings *	
1995	Burlington II	Hwy 2/52 and Burlington Heights Subdivision	3873	2323800	1162	Thiem Drilling	Coal Creek	$401,900	$40,667	
1996	Lehigh Rd I	Lehigh Road, approx 2 mi. E of Dickinson	9021	5412600	2706	Northern Improvement	Coal Creek	$445,650	$94,721	
1996	Parshall	Hwy 23 and R. Ruud Farm, ~ 2mi N of Parshall	2310	1386000	693	TCDI	Coal Creek	$161,538	$24,255	
1997	Beulah/Zap I	Manny's Bldg, Jct Hwys. 200 & 49	6746	4047600	2024	TCDI	AVS	$469,150	$70,833	
1997	Lehigh Rd II	Lehigh Road and Lehigh Drive	5000	3000000	1500	Northern Improvement	Coal Creek	$230,950	$52,500	
1998	Beulah/Zap II	Manny's Bldg, Jct Hwys. 200 & 49	6205	3723000	1862	Thiem Drilling	AVS	$311,812	$65,153	
1998	Lehigh Rd. III	Lehigh Road, Lehigh Drive, A. Binek Driveway	5000	3000000	1500	Northern Improvement	Coal Creek	$264,912	$52,500	
1999	Beulah/Zap III	Mercer Co. 21 and KHOL Radio	4961	2976600	1488	Earth, Energy, Water	AVS	$307,348	$52,091	
1999	Lehigh Rd IV	Lehigh Road and Lehigh Drive	3939	2363400	1182	Earth, Energy, Water	AVS	$221,273	$41,360	
		Total Grout 1995-1999	47055							
		Total Flyash 1995-1999		28233000	14117					
		Total Grouting Project Cost 1995-1999						$2,814,533		
		Cost Savings By Using Flyash 1995-1999*							$494,078	18%

* Cost savings by using fly ash were estimated by comparing a grout formulation using 400 lbs cement and no fly ash with one using 100 lbs cement and 600 lbs Flyash per cubic yard. Estimated delivered costs for cement and fly ash were \$100/ton and \$15/ton, respectively, based on a conversation with Donavon Meuchel (Earth, Energy and Water Systems), February 7, 2000. Average total savings per yard of grout by using AVS Fly Ash at Beulah and Lehigh 1999 Reclamation Projects was estimated to be \$10.50.

Components	Cost per ton	Cost per cwt	Cost per cyd
Cement	$100.00	$5.00	
Flyash	$15.00	$0.75	
400 lbs cement, 0 lbs flyash			$20.00
100 lbs cement, 600 lbs flyash			$9.50
Estimated Cost Savings Per Cubic Yard			$10.50

MANUAL FOR

ABANDONED UNDERGROUND MINE INVENTORY AND RISK ASSESSMENT



STATE OF OHIO DEPARTMENT OF TRANSPORTATION

MAY 15, 1998

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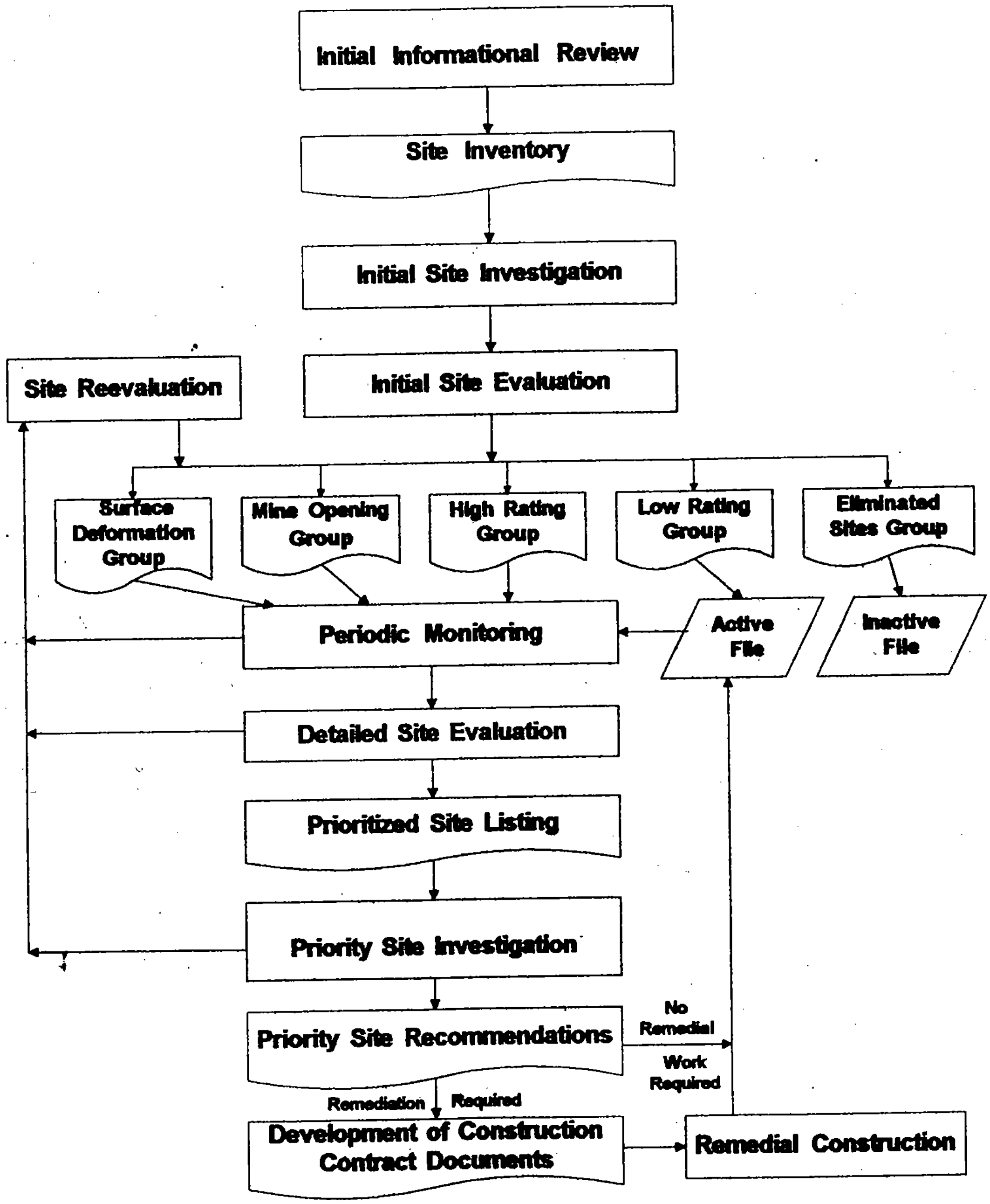
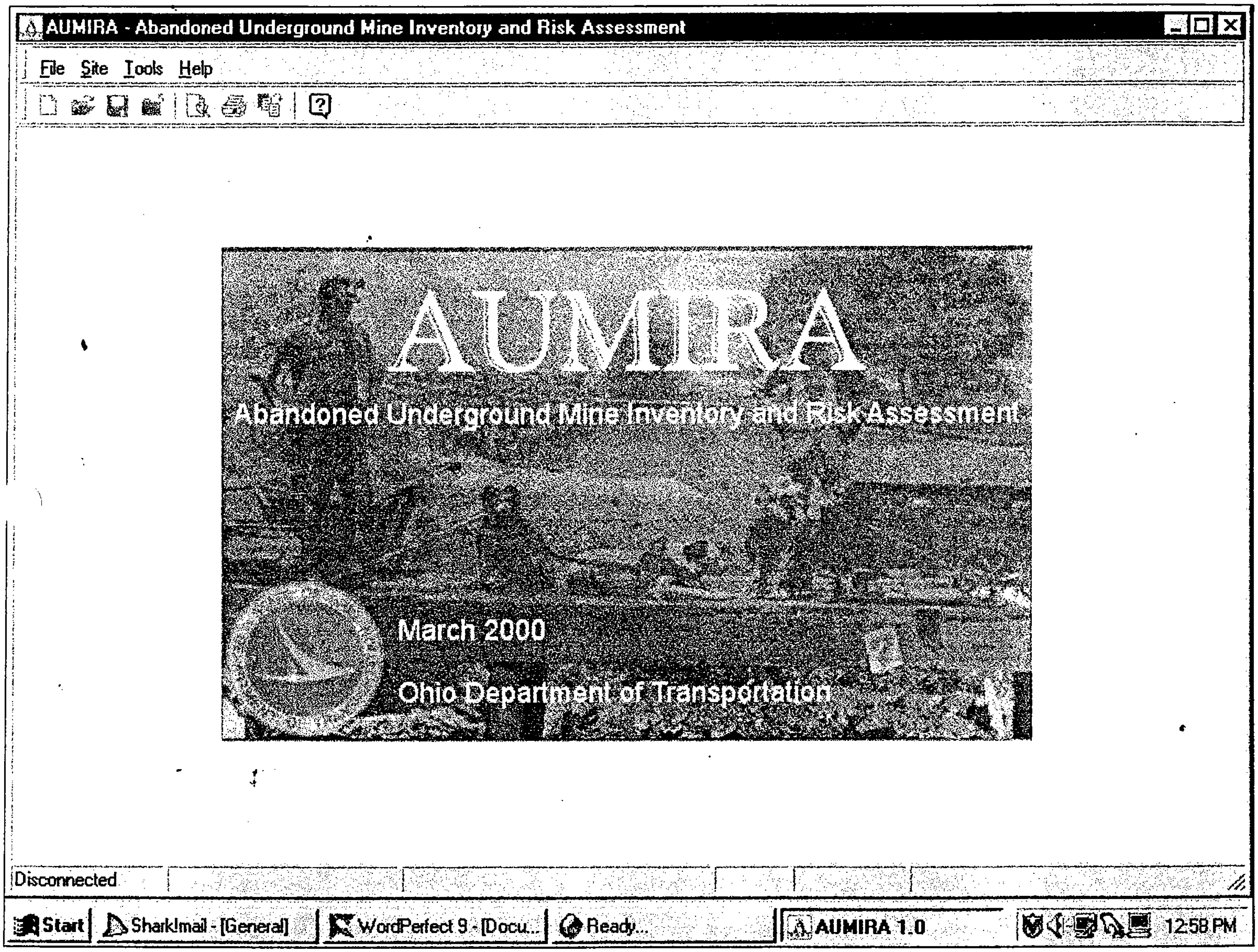
ABANDONED UNDERGROUND MINE INVENTORY AND RISK ASSESSMENT



L. RICK RUEGSEGGER, P. E.
Special Projects Coordinator

1600 West Broad Street, Room 2033
Columbus, Ohio 43223
614-275-1395
Fax: 614-275-1354
rruegse@dot.state.oh.us

OHIO DEPARTMENT OF
TRANSPORTATION
Bob Taft, Governor
Gordon Proctor, Director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AUMIRA
Abandoned Underground Mine Inventory and Risk Assessment
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Ohio Department of Transportation
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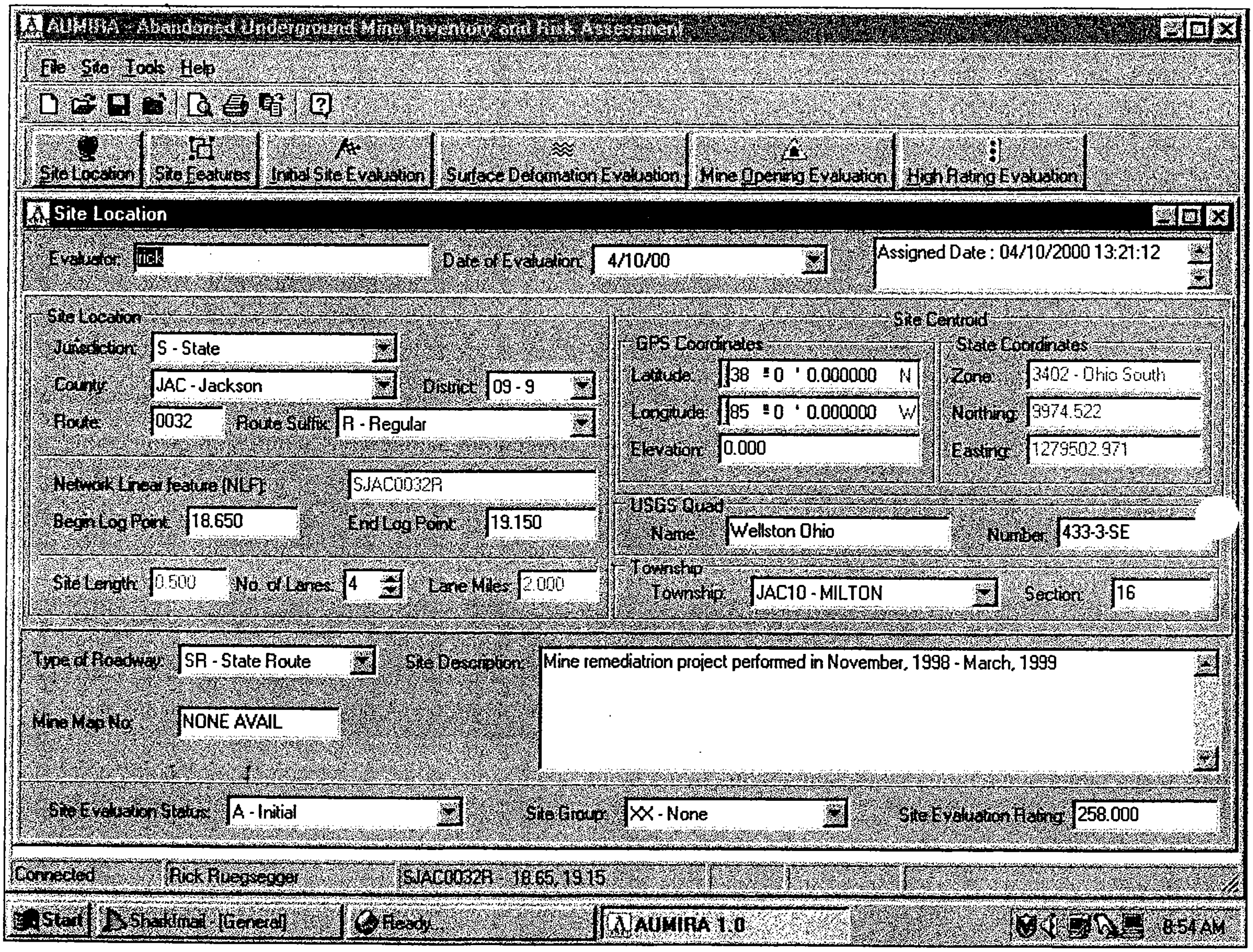
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Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Site Location
Evaluator: rick
Date of Evaluation: 4/10/00
Assigned Date : 04/10/2000 13:21:12
Site Location
Jurisdiction: S - State
County: JAC - Jackson
District: 09 - 9
Route: 0032
Route Suffix: R - Regular
Network Linear feature (NLF): SJAC0032R
Begin Log Point: 18.650
End Log Point: 19.150
Site Length: 0.500
No. of Lanes: 4
Lane Miles: 2.000
Site Centroid
GPS Coordinates
Latitude: 38 ° 0 ' 0.000000 N
Longitude: 85 ° 0 ' 0.000000 W
Elevation: 0.000
State Coordinates
Zone: 3402 - Ohio South
Northing: 9974.522
Easting: 1279502.971
USGS Quad
Name: Wellston Ohio
Number: 433-3-SE
Township
Township: JAC10 - MILTON
Section: 16
Type of Roadway: SR - State Route
Site Description: Mine remediatrion project performed in November, 1998 - March, 1999
Mine Map No: NONE AVAIL
Site Evaluation Status: A - Initial
Site Group: XX - None
Site Evaluation Rating: 258.000
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Rick Ruegsegger
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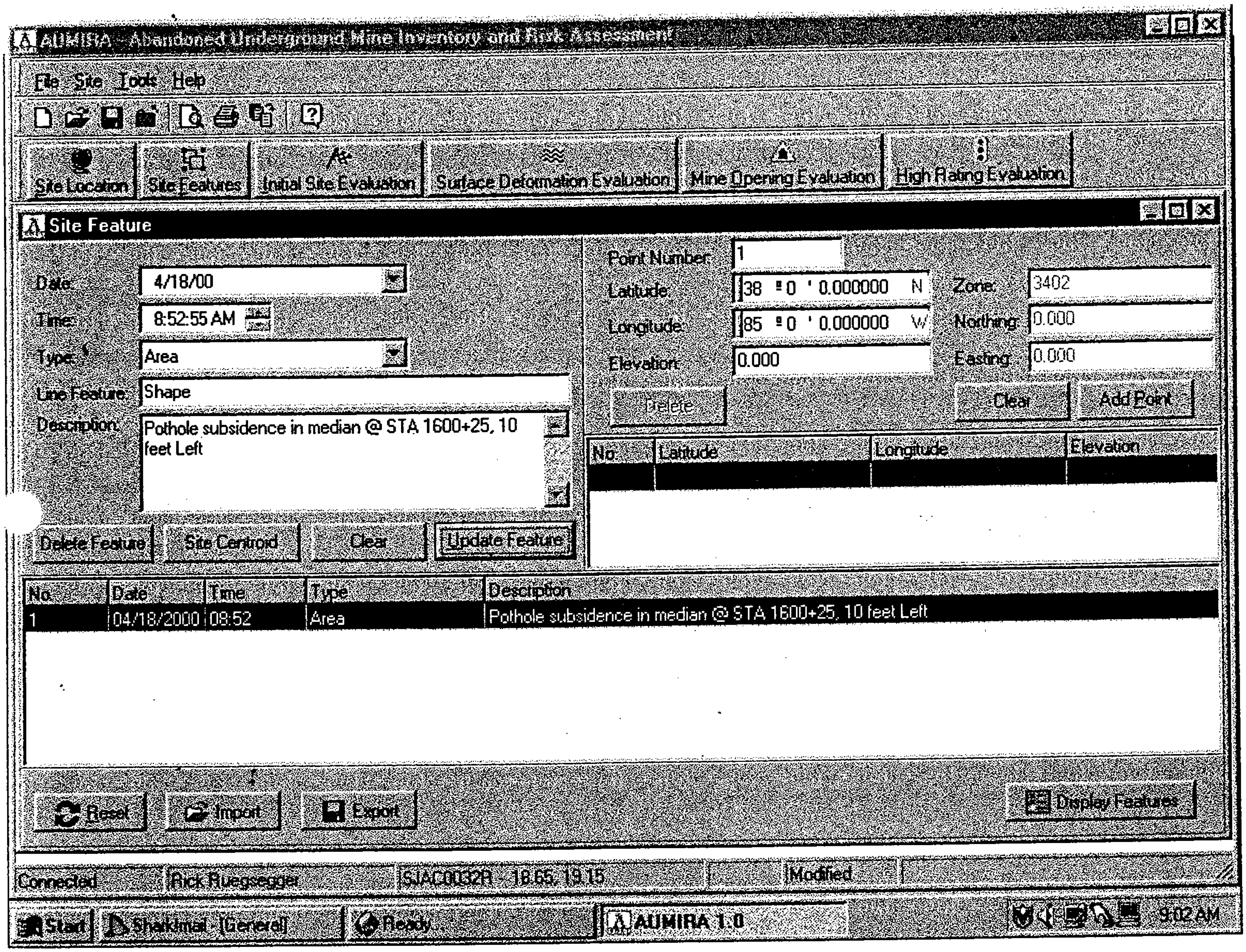
AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Site Feature
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Time: 8:52:55 AM
Type: Area
Line Feature: Shape
Description: Pothole subsidence in median @ STA 1600+25, 10 feet Left
Delete Feature
Site Centroid
Clear
Update Feature
Point Number: 1
Latitude: 38 º 0 ' 0.000000 N
Longitude: 85 º 0 ' 0.000000 W
Elevation: 0.000
Zone: 3402
Northing: 0.000
Easting: 0.000
Delete
Clear
Add Point
No. Latitude Longitude Elevation
No. Date Time Type Description
1 04/18/2000 08:52 Area Pothole subsidence in median @ STA 1600+25, 10 feet Left
Reset
Import
Export
Display Features
Connected
Rick Ruegsegger
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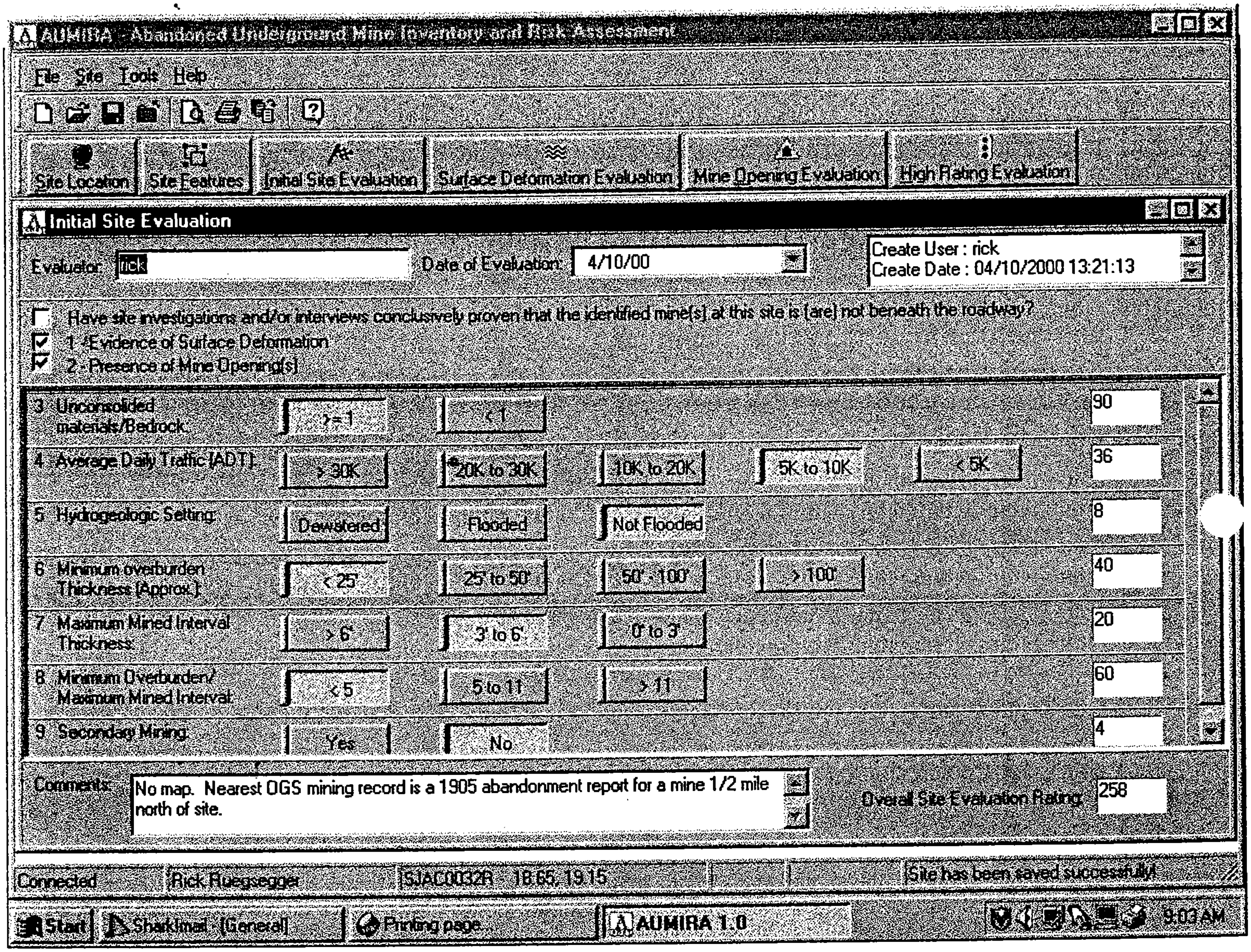
AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Initial Site Evaluation
Evaluator: rick
Date of Evaluation: 4/10/00
Create User : rick
Create Date : 04/10/2000 13:21:13
Have site investigations and/or interviews conclusively proven that the identified mine(s) at this site is (are) not beneath the roadway?
1 - Evidence of Surface Deformation
2 - Presence of Mine Opening(s)
3 Unconsolided materials/Bedrock: >=1 | <1 | 90
4 Average Daily Traffic (ADT): > 30K | 20K to 30K | 10K to 20K | 5K to 10K | < 5K | 36
5 Hydrogeologic Setting: Dewatered | Flooded | Not Flooded | 8
6 Minimum overburden Thickness (Approx.): < 25' | 25' to 50' | 50' - 100' | > 100' | 40
7 Maximum Mined Interval Thickness: > 6' | 3' to 6' | 0' to 3' | 20
8 Minimum Overburden/ Maximum Mined Interval: < 5 | 5 to 11 | > 11 | 60
9 Secondary Mining: Yes | No | 4
Comments: No map. Nearest OGS mining record is a 1905 abandonment report for a mine 1/2 mile north of site.
Overall Site Evaluation Rating: 258
Connected
Rick Ruegsegger
SJAC0032R 18.65, 19.15
Site has been saved successfully!
Start
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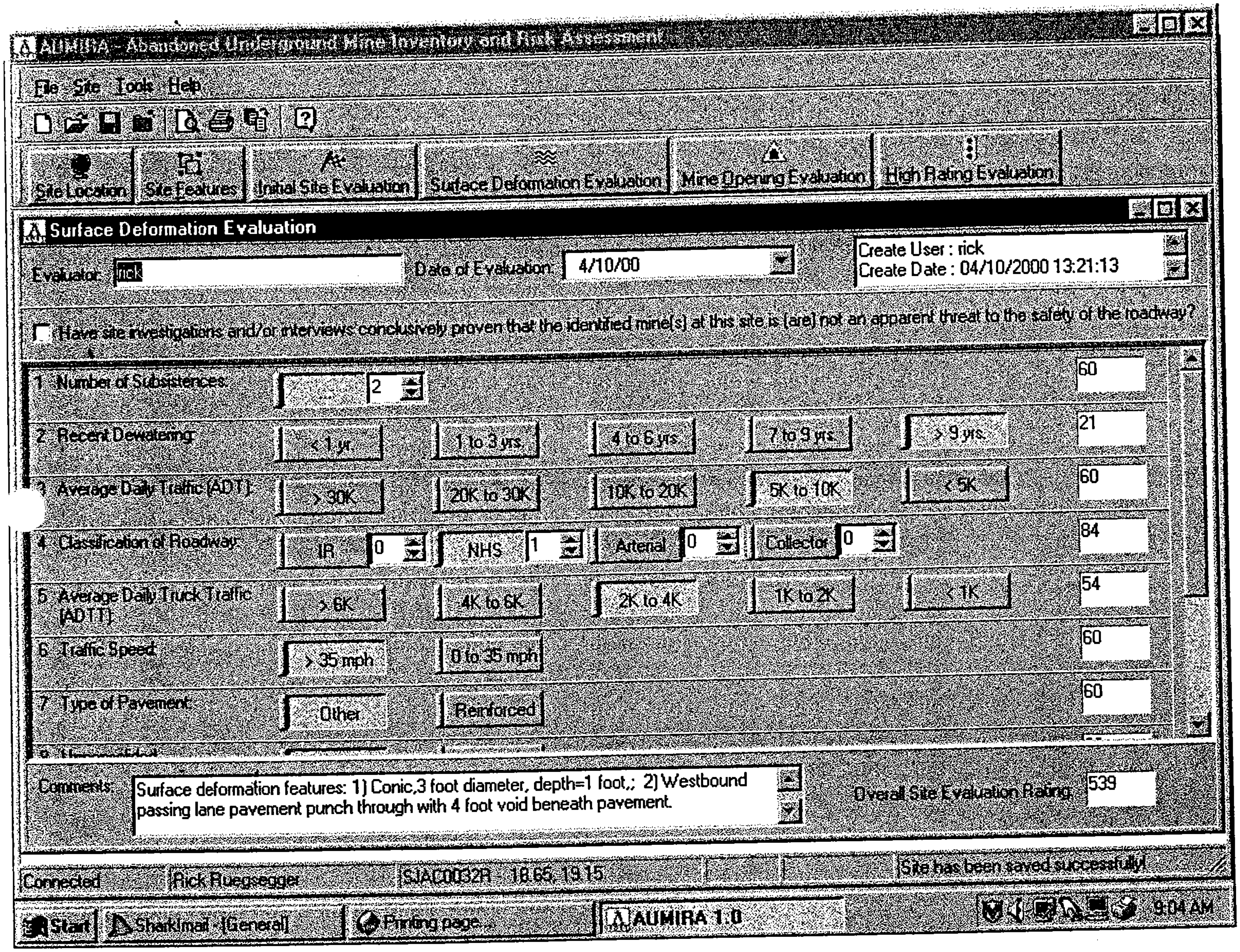
Printing page...
AUMIRA 1.0
9:03 AM


AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Surface Deformation Evaluation
Evaluator: rick
Date of Evaluation: 4/10/00
Create User : rick
Create Date : 04/10/2000 13:21:13
Have site investigations and/or interviews conclusively proven that the identified mine(s) at this site is (are) not an apparent threat to the safety of the roadway?
1 Number of Subsistences: 2
60
2 Recent Dewatering:
< 1 yr.
1 to 3 yrs.
4 to 6 yrs.
7 to 9 yrs.
> 9 yrs.
21
3 Average Daily Traffic (ADT):
> 30K
20K to 30K
10K to 20K
5K to 10K
< 5K
60
4 Classification of Roadway:
IR 0
NHS 1
Arterial 0
Collector 0
84
5 Average Daily Truck Traffic (ADTT):
> 6K
4K to 6K
2K to 4K
1K to 2K
< 1K
54
6 Traffic Speed:
> 35 mph
0 to 35 mph
60
7 Type of Pavement:
Other
Reinforced
60
Comments: Surface deformation features: 1) Conic,3 foot diameter, depth=1 foot,; 2) Westbound passing lane pavement punch through with 4 foot void beneath pavement.
Overall Site Evaluation Rating 539
Connected
Rick Ruegsegger
SJAC0032R - 18.65, 19.15
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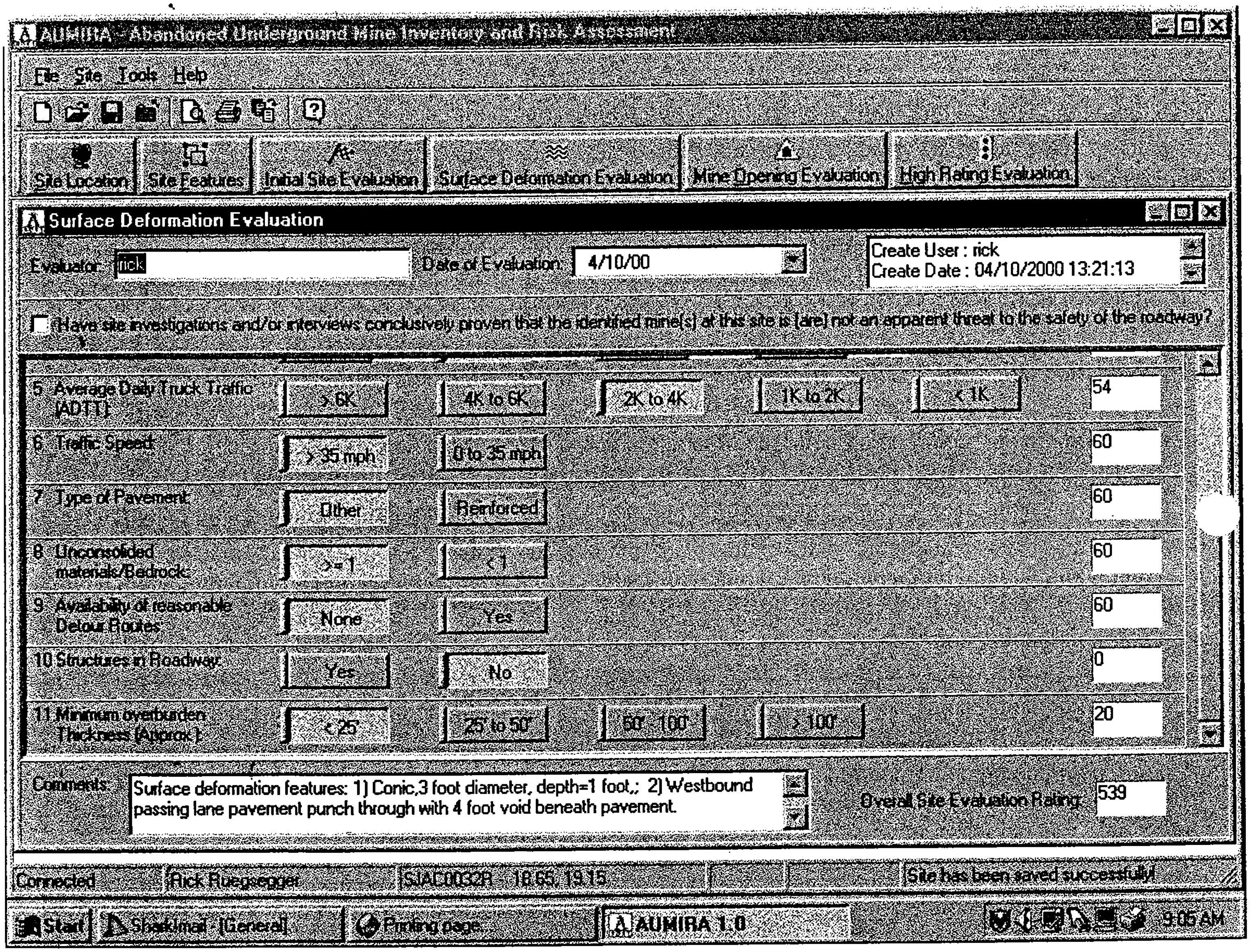
AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Surface Deformation Evaluation
Evaluator: rick
Date of Evaluation: 4/10/00
Create User : rick
Create Date : 04/10/2000 13:21:13
Have site investigations and/or interviews conclusively proven that the identified mine(s) at this site is (are) not an apparent threat to the safety of the roadway?
5 Average Daily Truck Traffic (ADTT)
> 6K
4K to 6K
2K to 4K
1K to 2K
< 1K
54
6 Traffic Speed
> 35 mph
0 to 35 mph
60
7 Type of Pavement
Other
Reinforced
60
8 Unconsolidated materials/Bedrock
>=1
<1
60
9 Availability of reasonable Detour Routes
None
Yes
60
10 Structures in Roadway
Yes
No
0
11 Minimum overburden Thickness (Approx.)
< 25'
25' to 50'
50' - 100'
> 100'
20
Comments:
Surface deformation features: 1) Conic,3 foot diameter, depth=1 foot,; 2) Westbound passing lane pavement punch through with 4 foot void beneath pavement.
Overall Site Evaluation Rating: 539
Connected
Rick Ruegsegger
SJAC0032R - 18.65, 19.15
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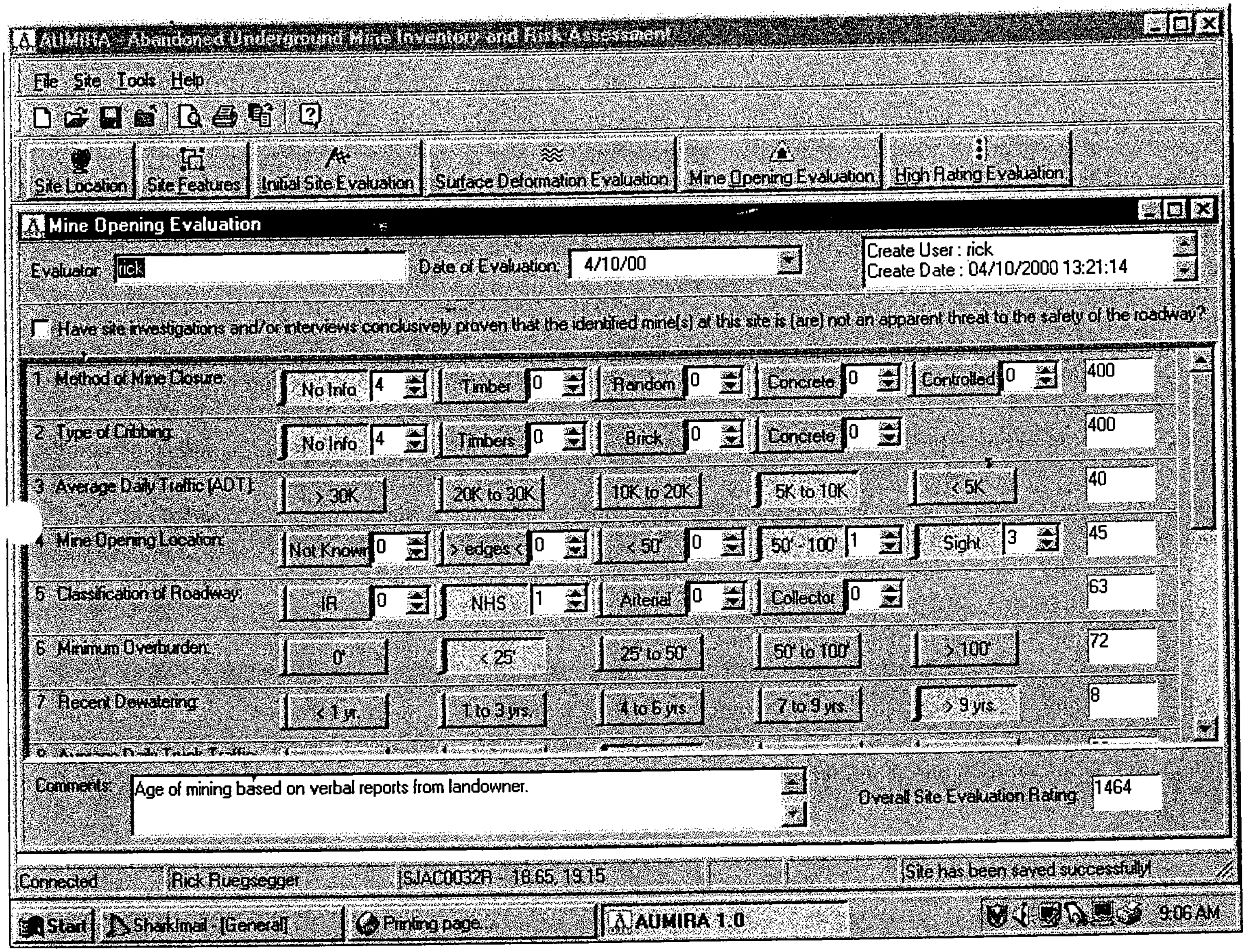
AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Mine Opening Evaluation
Evaluator: rick
Date of Evaluation: 4/10/00
Create User : rick
Create Date : 04/10/2000 13:21:14
Have site investigations and/or interviews conclusively proven that the identified mine(s) at this site is (are) not an apparent threat to the safety of the roadway?
1 Method of Mine Closure: No Info 4 Timber 0 Random 0 Concrete 0 Controlled 0 400
2 Type of Cribbing: No Info 4 Timbers 0 Brick 0 Concrete 0 400
3 Average Daily Traffic (ADT): > 30K 20K to 30K 10K to 20K 5K to 10K < 5K 40
4 Mine Opening Location: Not Known 0 > edges < 0 < 50' 0 50' - 100' 1 Sight 3 45
5 Classification of Roadway: IR 0 NHS 1 Arterial 0 Collector 0 63
6 Minimum Overburden: 0' < 25' 25' to 50' 50' to 100' > 100' 72
7 Recent Dewatering: < 1 yr. 1 to 3 yrs. 4 to 6 yrs. 7 to 9 yrs. > 9 yrs. 8
Comments: Age of mining based on verbal reports from landowner.
Overall Site Evaluation Rating: 1464
Connected
Rick Ruegsegger
SJAC0032R - 18.65, 19.15
Site has been saved successfully!
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Sharkmail - [General]
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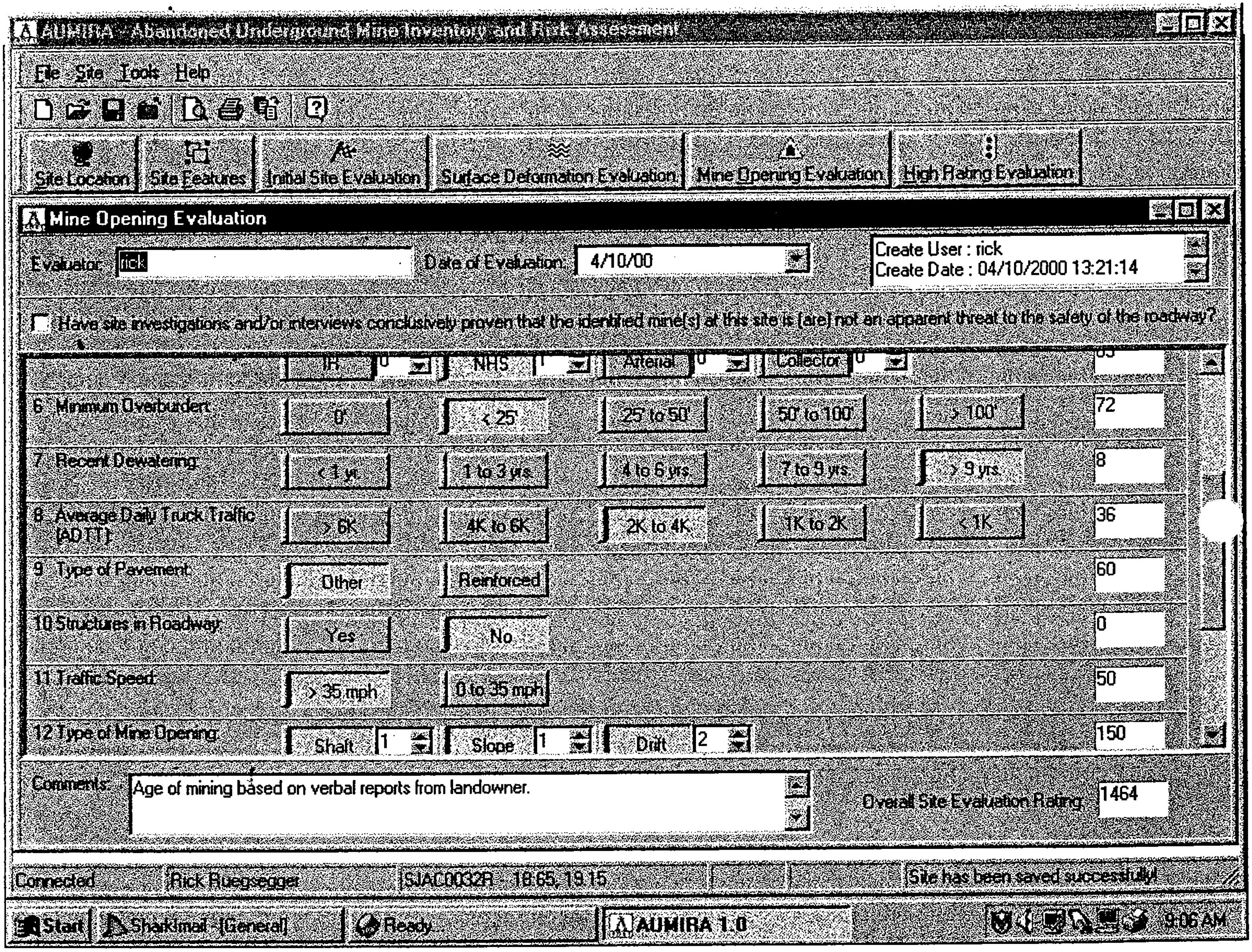
AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Mine Opening Evaluation
Evaluator: rick
Date of Evaluation: 4/10/00
Create User : rick
Create Date : 04/10/2000 13:21:14
Have site investigations and/or interviews conclusively proven that the identified mine(s) at this site is (are) not an apparent threat to the safety of the roadway?
IR 0 NHS 1 Arterial 0 Collector 0
6 Minimum Overburden: 0' < 25' 25' to 50' 50' to 100' > 100' 72
7 Recent Dewatering: < 1 yr. 1 to 3 yrs. 4 to 6 yrs. 7 to 9 yrs. > 9 yrs. 8
8 Average Daily Truck Traffic (ADTT): > 6K 4K to 6K 2K to 4K 1K to 2K < 1K 36
9 Type of Pavement: Other Reinforced 60
10 Structures in Roadway: Yes No 0
11 Traffic Speed: > 35 mph 0 to 35 mph 50
12 Type of Mine Opening: Shaft 1 Slope 1 Drift 2 150
Comments: Age of mining based on verbal reports from landowner.
Overall Site Evaluation Rating 1464
Connected
Rick Ruegsegger
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AUMIRA 1.0
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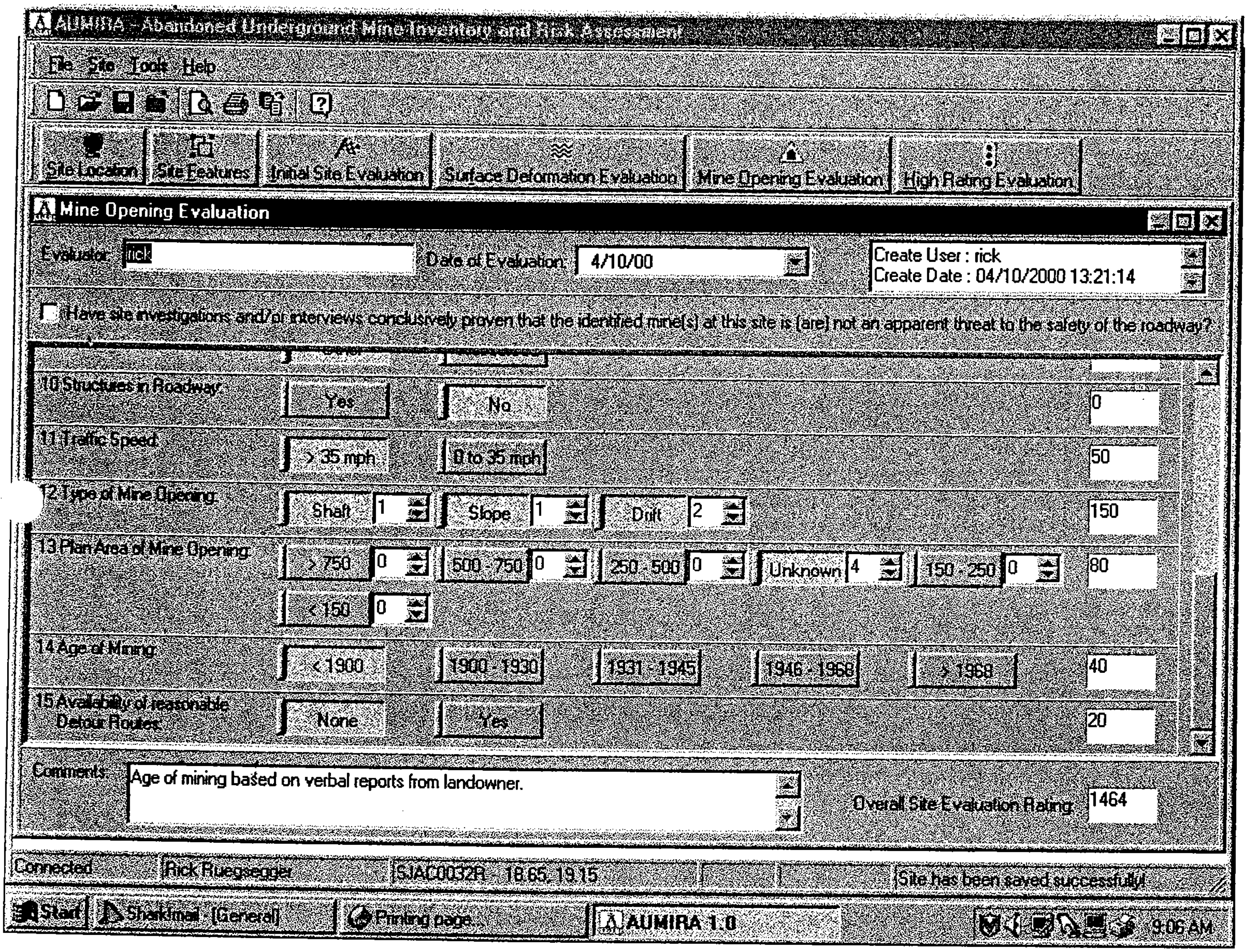
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File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Mine Opening Evaluation
Evaluator: rick
Date of Evaluation: 4/10/00
Create User : rick
Create Date : 04/10/2000 13:21:14
Have site investigations and/or interviews conclusively proven that the identified mine(s) at this site is (are) not an apparent threat to the safety of the roadway?
10 Structures in Roadway: Yes No 0
11 Traffic Speed: > 35 mph 0 to 35 mph 50
12 Type of Mine Opening: Shaft 1 Slope 1 Drift 2 150
13 Plan Area of Mine Opening: > 750 0 500 - 750 0 250 - 500 0 Unknown 4 150 - 250 0 80
< 150 0
14 Age of Mining: < 1900 1900 - 1930 1931 - 1945 1946 - 1968 > 1968 40
15 Availability of reasonable Detour Routes: None Yes 20
Comments: Age of mining based on verbal reports from landowner.
Overall Site Evaluation Rating: 1464
Connected
Rick Ruegsegger
SJAC0032R - 18.65, 19.15
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Sharkmail - [General]
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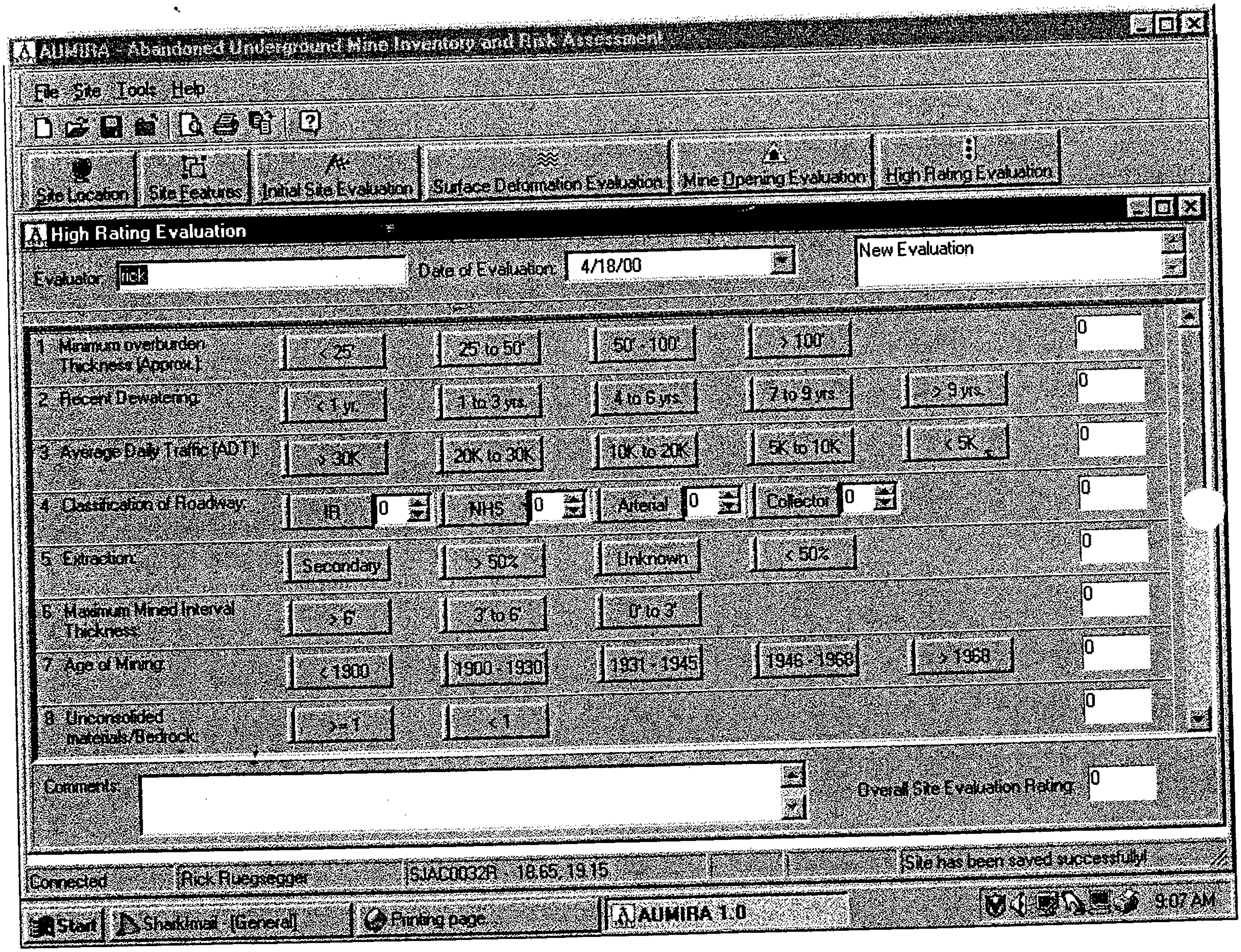
9:06 AM


AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
High Rating Evaluation
Evaluator: rick
Date of Evaluation: 4/18/00
New Evaluation
1. Minimum overburden Thickness (Approx.):
< 25'
25' to 50'
50' - 100'
> 100'
2. Recent Dewatering:
< 1 yr.
1 to 3 yrs.
4 to 6 yrs.
7 to 9 yrs.
> 9 yrs.
3. Average Daily Traffic (ADT):
> 30K
20K to 30K
10K to 20K
5K to 10K
< 5K
4. Classification of Roadway:
IR
NHS
Arterial
Collector
5. Extraction:
Secondary
> 50%
Unknown
< 50%
6. Maximum Mined Interval Thickness:
> 6'
3' to 6'
0' to 3'
7. Age of Mining:
< 1900
1900 - 1930
1931 - 1945
1946 - 1968
> 1968
8. Unconsolided materials/Bedrock:
>= 1
< 1
Comments:
Overall Site Evaluation Rating:
Site has been saved successfully!
Connected
Rick Ruegsegger
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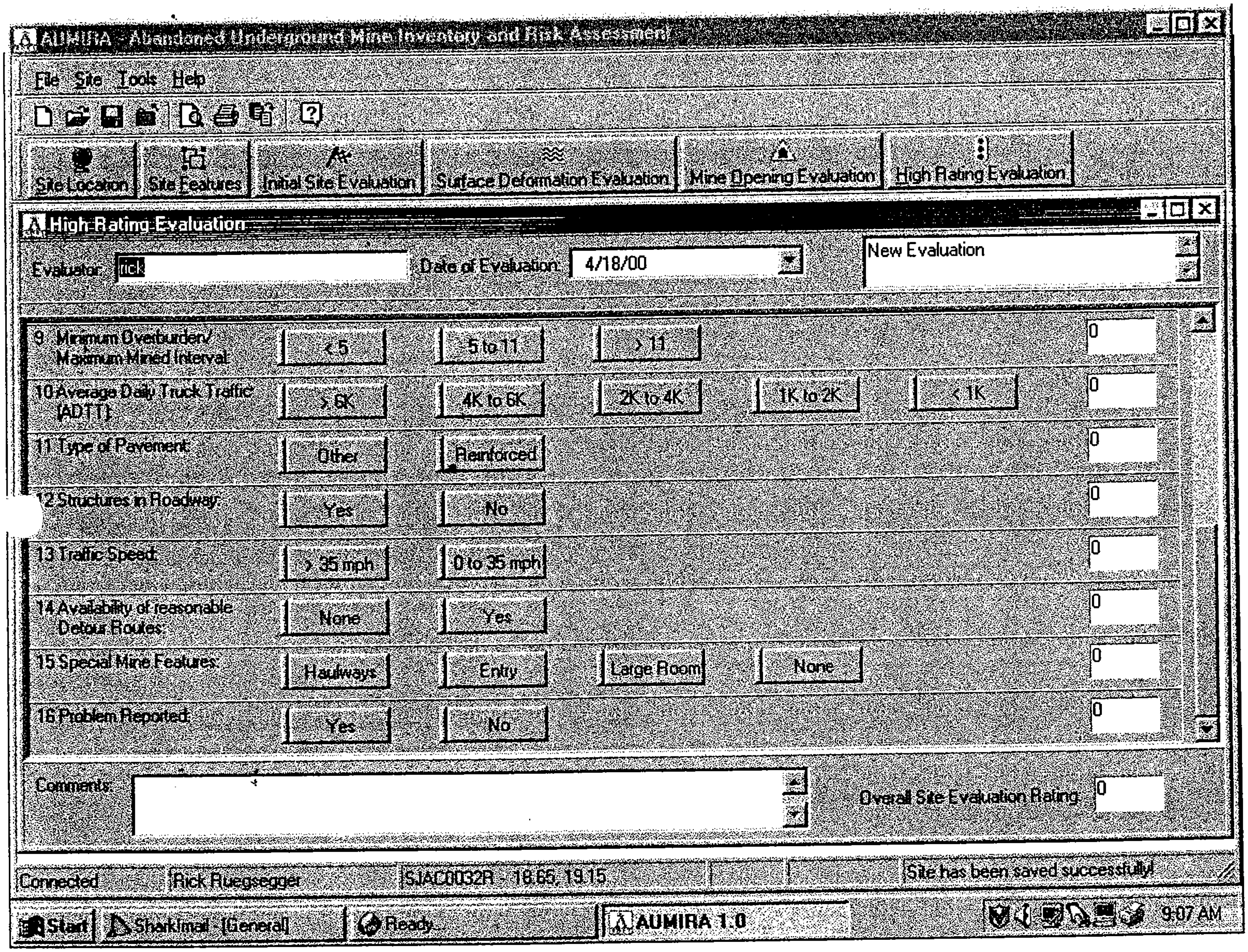
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File Site Tools Help
Site Location
Site Features
Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
High Rating Evaluation
Evaluator: rick
Date of Evaluation: 4/18/00
New Evaluation
9 Minimum Overburden/ Maximum Mined Interval:
< 5
5 to 11
> 11
0
10 Average Daily Truck Traffic (ADTT):
> 6K
4K to 6K
2K to 4K
1K to 2K
< 1K
0
11 Type of Pavement:
Other
Reinforced
0
12 Structures in Roadway:
Yes
No
0
13 Traffic Speed:
> 35 mph
0 to 35 mph
0
14 Availability of reasonable Detour Routes:
None
Yes
0
15 Special Mine Features:
Haulways
Entry
Large Room
None
0
16 Problem Reported:
Yes
No
0
Comments:
Overall Site Evaluation Rating: 0
Connected
Rick Ruegsegger
SJAC0032R - 18.65, 19.15
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Ready
AUMIRA 1.0
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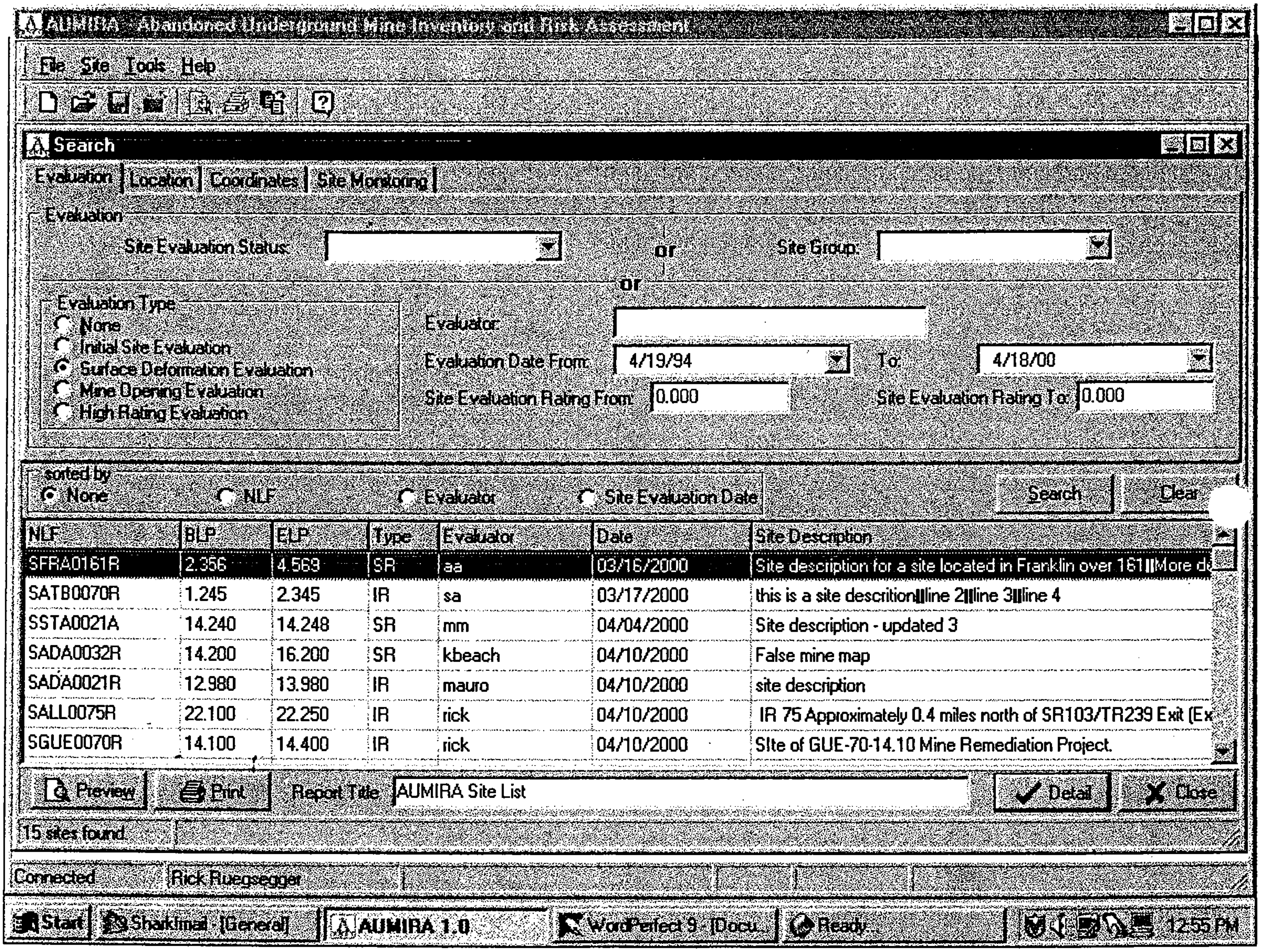
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File Site Tools Help
Search
Evaluation Location Coordinates Site Monitoring
Evaluation
Site Evaluation Status:
or
Site Group:
or
Evaluation Type
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Initial Site Evaluation
Surface Deformation Evaluation
Mine Opening Evaluation
High Rating Evaluation
Evaluator:
Evaluation Date From: 4/19/94
To: 4/18/00
Site Evaluation Rating From: 0.000
Site Evaluation Rating To: 0.000
sorted by
None
NLF
Evaluator
Site Evaluation Date
Search
Clear
NLF BLP ELP Type Evaluator Date Site Description
SFRA0161R 2.356 4.569 SR aa 03/16/2000 Site description for a site located in Franklin over 161
SATB0070R 1.245 2.345 IR sa 03/17/2000 this is a site descrition line 2 line 3 line 4
SSTA0021A 14.240 14.248 SR mm 04/04/2000 Site description - updated 3
SADA0032R 14.200 16.200 SR kbeach 04/10/2000 False mine map
SADA0021R 12.980 13.980 IR mauro 04/10/2000 site description
SALL0075R 22.100 22.250 IR rick 04/10/2000 IR 75 Approximately 0.4 miles north of SR103/TR239 Exit
SGUE0070R 14.100 14.400 IR rick 04/10/2000 SIte of GUE-70-14.10 Mine Remediation Project.
Preview
Print
Report Title AUMIRA Site List
Detail
Close
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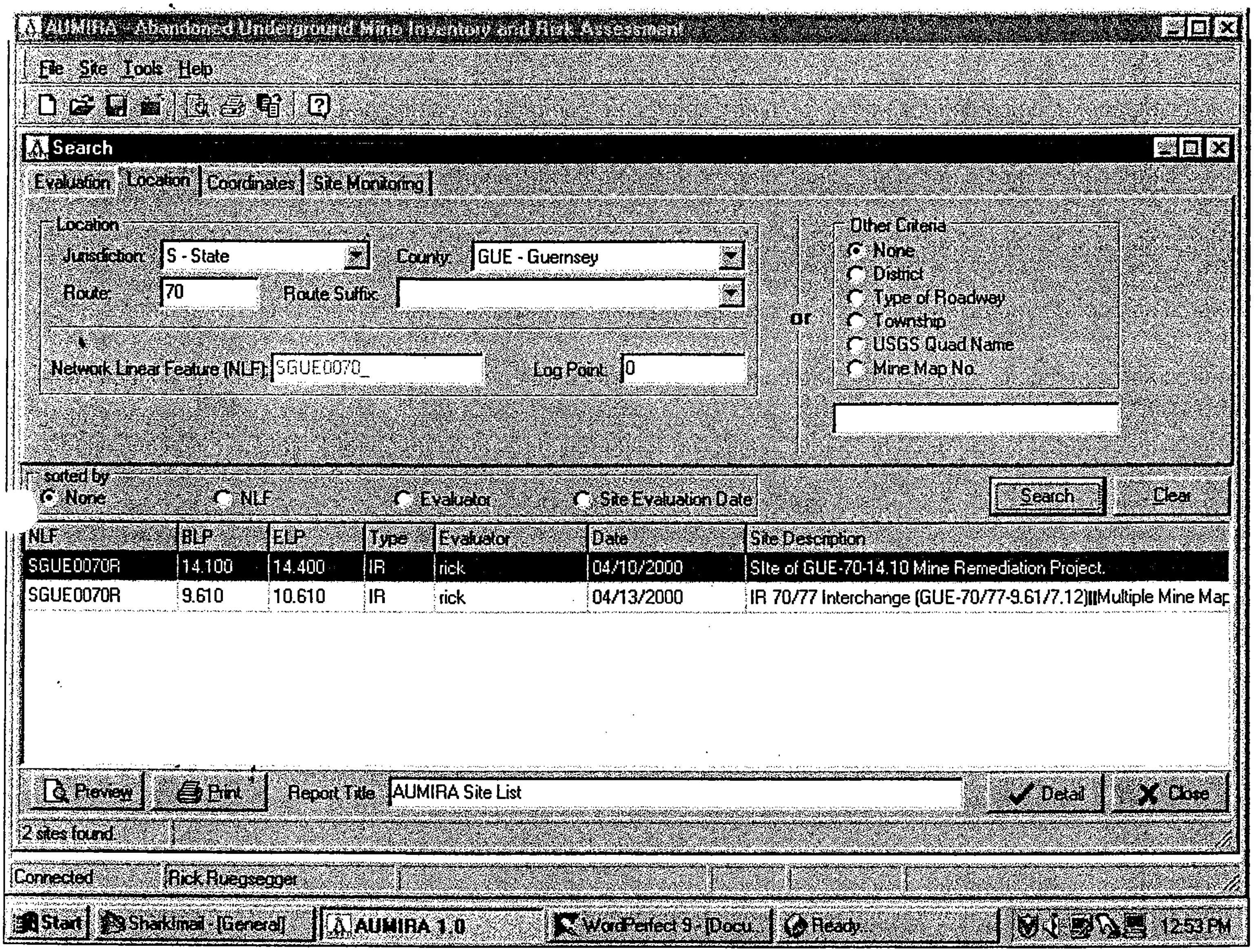
AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Search
Evaluation Location Coordinates Site Monitoring
Location
Jurisdiction: S - State
County: GUE - Guernsey
Route: 70
Route Suffix:
or
Network Linear Feature (NLF): SGUE0070_
Log Point: 0
Other Criteria
None
District
Type of Roadway
Township
USGS Quad Name
Mine Map No.
sorted by
None
NLF
Evaluator
Site Evaluation Date
Search
Clear
NLF BLP ELP Type Evaluator Date Site Description
SGUE0070R 14.100 14.400 IR rick 04/10/2000 Site of GUE-70-14.10 Mine Remediation Project.
SGUE0070R 9.610 10.610 IR rick 04/13/2000 IR 70/77 Interchange (GUE-70/77-9.61/7.12)Multiple Mine Map
Preview
Print
Report Title AUMIRA Site List
Detail
Close
2 sites found
Connected
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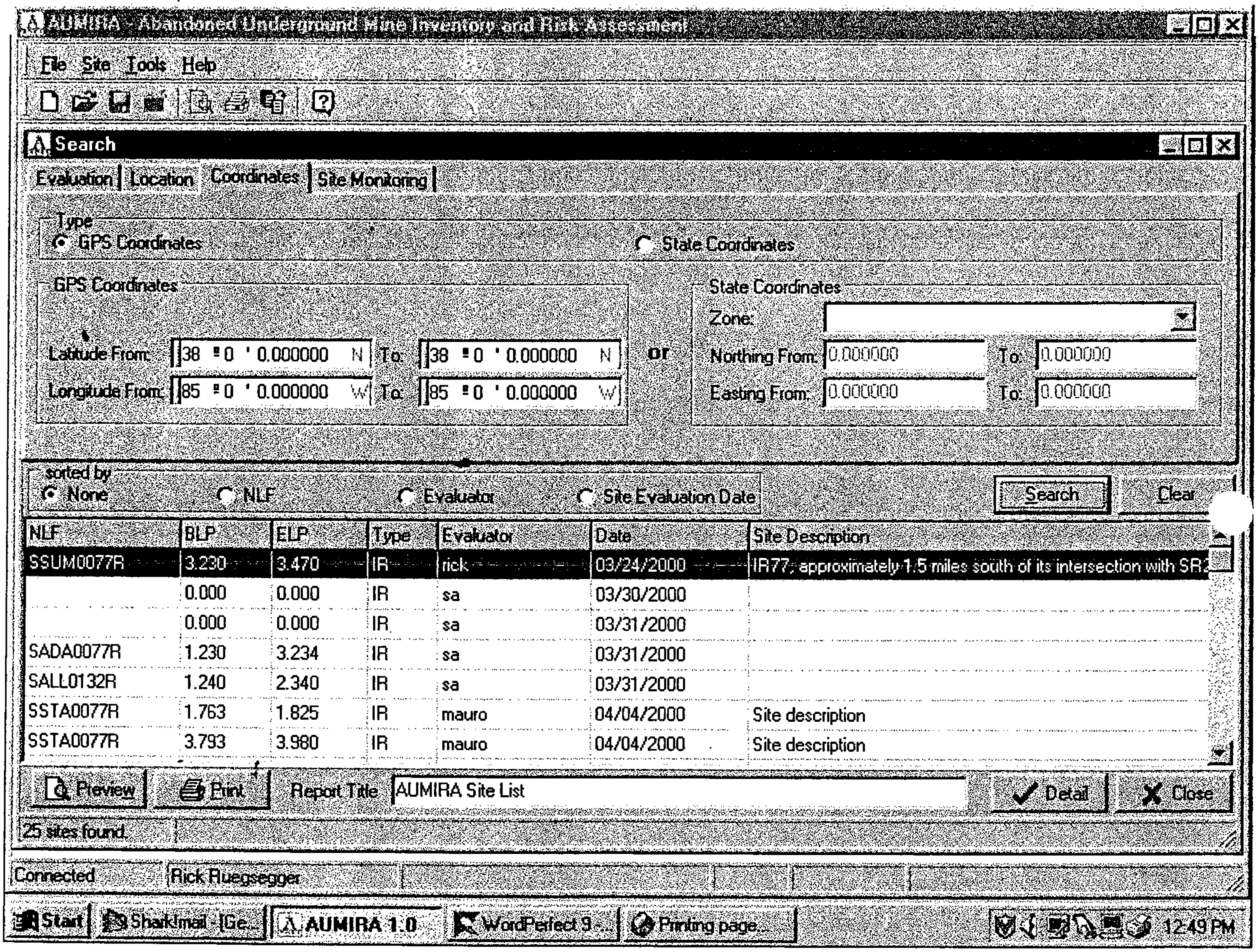
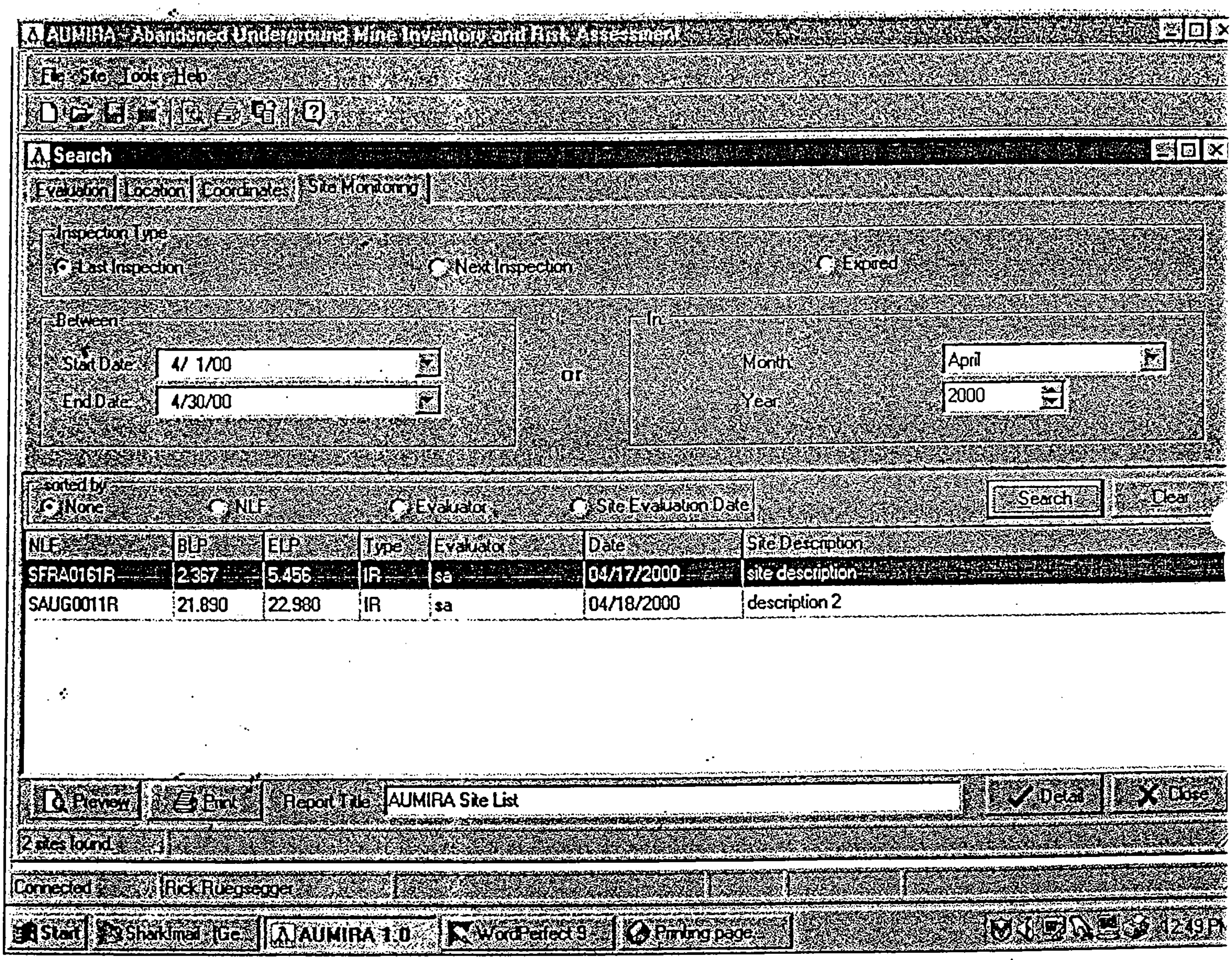
WordPerfect 9 - [Docu...
Ready
12:53 PM


AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Search
Evaluation Location Coordinates Site Monitoring
Type
GPS Coordinates
State Coordinates
GPS Coordinates
Latitude From: 38 ° 0 ' 0.000000 N To: 38 ° 0 ' 0.000000 N
Longitude From: 85 ° 0 ' 0.000000 W To: 85 ° 0 ' 0.000000 W
or
State Coordinates
Zone:
Northing From: 0.000000 To: 0.000000
Easting From: 0.000000 To: 0.000000
sorted by
None
NLF
Evaluator
Site Evaluation Date
Search
Clear
NLF BLP ELP Type Evaluator Date Site Description
SSUM0077R 3.230 3.470 IR rick 03/24/2000 IR77, approximately 1.5 miles south of its intersection with SR2
0.000 0.000 IR sa 03/30/2000
0.000 0.000 IR sa 03/31/2000
SADA0077R 1.230 3.234 IR sa 03/31/2000
SALL0132R 1.240 2.340 IR sa 03/31/2000
SSTA0077R 1.763 1.825 IR mauro 04/04/2000 Site description
SSTA0077R 3.793 3.980 IR mauro 04/04/2000 Site description
Preview
Print
Report Title AUMIRA Site List
Detail
Close
25 sites found
Connected
Rick Ruegsegger
Start
Sharkmail - [Ge...
AUMIRA 1.0
WordPerfect 9 -...
Printing page...
12:49 PM


AUMIRA - Abandoned Underground Mine Inventory and Risk Assessment
File Site Tools Help
Search
Evaluation Location Coordinates Site Monitoring
Inspection Type
Last Inspection
Next Inspection
Expired
Between
Start Date 4/ 1/00
End Date 4/30/00
or
In
Month April
Year 2000
sorted by
None
NLF
Evaluator
Site Evaluation Date
Search
Clear
NLF BLP ELP Type Evaluator Date Site Description
SFRA0161R 2.367 5.456 IR sa 04/17/2000 site description
SAUG0011R 21.890 22.980 IR sa 04/18/2000 description 2
Preview
Print
Report Title AUMIRA Site List
Detail
Close
2 sites found.
Connected
Rick Ruegsegger
Start
Sharkmail - [Ge
AUMIRA 1.0
WordPerfect 9
Printing page
12:49 PM

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